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THESIS

APPLICATION OF ATM TECHNOLOGY TO THE SYSTEMS MANAGEMENT DEPARTMENT COMPUTER LABORATORY NETWORK

by

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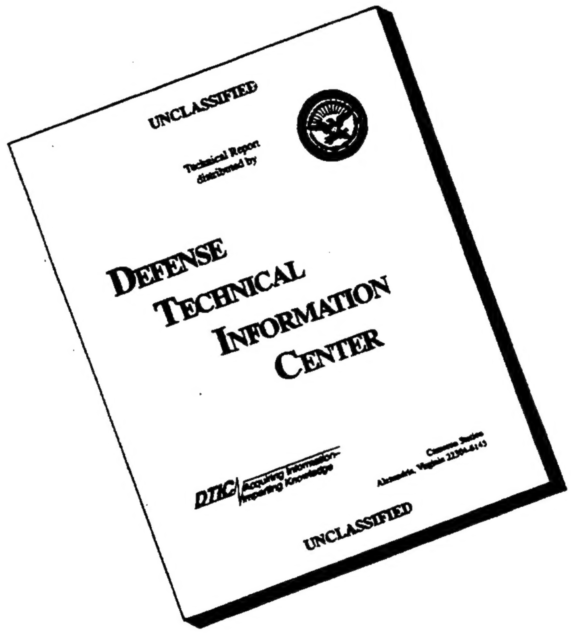

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13. ABSTRACT *(maximum 200 words)*

Since the appearance of Local Area Networks (LANs), their use and bandwidth consumption have increased considerably. Users are now seeking new technologies to satisfy their bandwidth demand. Many consider ATM as the solution to their needs. Though ATM is fairly new networking technology, it has made several strides, and is now considered a viable technology that is applicable in a LAN environment. However, migrating from today's shared-medium LANs (Token-Ring and Ethernet) to an ATM LAN exposes an organization to difficulties, risks, and costs. A well-thoughtout migration strategy reduces the impact of these factors while implementing ATM technology.

This study reviews ATM technology and its application in a LAN environment, evaluates the Systems Management Department Computer Lab LAN, redesign the LAN using ATM technology, and develops an evolutionary strategy to implement the proposed ATM LAN.

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APPLICATION OF ATM TECHNOLOGY TO THE SYSTEMS MANAGEMENT DEPARTMENT COMPUTER LABORATORY NETWORK

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ABSTRACT

Since the appearance of Local Area Networks (LANs), their use and bandwidth consumption have increased considerably. Users are now seeking new technologies to satisfy their bandwidth demand. Many consider ATM as the solution to their needs. Though ATM is fairly new networking technology, it has made several strides, and is now considered a viable technology that is applicable in a LAN environment. However, migrating from today's shared-medium LANs (Token-Ring and Ethernet) to an ATM LAN exposes an organization to difficulties, risks, and costs. A well-thoughtout migration strategy reduces the impact of these factors while implementing ATM technology.

This study reviews ATM technology and its application in a LAN environment, evaluates the Systems Management Department Computer Lab LAN, redesign the LAN using ATM technology, and develops an evolutionary strategy to implement the proposed ATM LAN.

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I. INTRODUCTION

A. BACKGROUND

Since the appearance of Local Area Networks (LANs), their use and bandwidth consumption have increased considerably. As more users access the LANs, and their applications capability (text, graphics, and video intensity) increases, higher bandwidth will be required. No longer is the "normal" 10 or 16 megabits per second (Mbps) pipes the typical option when installing new LANs or upgrading existing ones. Users are now asking for substantial increases in bandwidth to meet their application-intensive bandwidth requirements, and to allow multiple simultaneous access to the pipes.

New technologies have emerged to satisfy this demand for bandwidth. They include Fast Ethernet (100 Mbps), Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM).

Cost is a major driving factor in deciding to adapt new LAN technology. User will always pose the question, how much will it cost to install the new technology? In the case of ATM, users are also asking themselves, do I want to be the first to implement an ATM network, and what are my risks?

ATM has made several strides, and is now considered as a viable technology that is applicable in the LAN environment. Although ATM was originally developed as an international standard for Synchronous Optical Network (SONET)-based Wide Area Networks (WANs), its attractiveness for LANs has resulted in ATM LANs appearing well in advanced of long-haul ATM services. The Army High-Performance Computer Research Center performed experiments in 1993 to evaluate the capability of ATM satisfying the communications needs of distributed networking computing. The results revealed that network computing is very promising over Local ATM Networks.

B. PURPOSE

The purpose of this thesis is to redesign the Systems Management (SM) Department's computer lab LANs using ATM technology. The research entails reviewing

ATM technology, assessing the existing computer lab LANs, redesigning the lab LANs, and devising a strategy to upgrade the current LANs to an Local ATM Network.

C. SCOPE AND METHODOLOGY

The main focus of this research is to review ATM technology and its possible use in a LAN environment; perform an in depth study of the existing SM Department computer lab LANs in Ingersoll IN-158, IN-224, and IN-250; redesign the current lab network; and the development of an evolutionary strategy to implement the proposed ATM LAN.

The research will entail a review of current books, periodicals and news articles on LANs, ATM technology, and Local ATM Networks. Academic and professional specialists will also be interviewed. These specialists will have been involved in the development of LANs and WANs, and have an understanding of the ATM technology. My emphasis will be on hardware and software required to implement the Local ATM Network, and the hardware and software compatibility issues that may occur when running existing applications on a Local ATM Network.

D. ORGANIZATION OF STUDY

Before delving into converting an existing LAN to a Local ATM Network, one should have a clear understanding of ATM, its application in a local environment, and implementation issues associated with ATM. Because these areas will play a crucial part in upgrading the SM computer lab LANs, I have devoted Chapters II and III to these topics. The remaining chapters cover an assessment of the SM lab LANs, the application of ATM technology to the LANs, and a migration strategy to convert or upgrade the SM lab LANs to an ATM LAN. The final chapter provides a conclusion of my research.

II. ASYNCHRONOUS TRANSFER MODE (ATM) TECHNOLOGY

A. INTRODUCTION

1. Purpose of Chapter

The purpose of this chapter is to provide a basic concept of ATM. An overview of ATM's functionality is given, and standardization issues are discussed. The information presented in this chapter gives a general understanding of ATM. In-depth information can be obtained in the resources provided in the List of References and the Bibliography.

2. Evolution of ATM

To better understand the evolution of ATM, a brief look at pre-ATM technologies (circuit switching, packet switching, and frame relay) is required. These technologies are in use today. However, as user requirements have increased, so has the need to transfer information in faster and more efficient modes. New applications are being implemented which require higher bandwidth, better quality of services, and the new transfer mode (ATM). Some applications functions properly using older and slower technologies.

a. Circuit Switching

Circuit switching is a transfer technology that has been used in the telephone system since the advent of telephones. The Plain Old Telephone System (POTS) uses circuit switching technology. POTS establishes a circuit, path, or connection to set up the call and maintains the connection for the duration of the call. However, both parties must be available at their respective node to establish the connection. The path terminates when one of the users breaks the connection by "hanging up" the receiver.

Though circuit switching was originally designed for telephone communications, it has found tremendous use in data transfer. Many users use this transfer mode for traffic that is time sensitive, has a constant bit rate, and regular transmission intervals.

Circuit switching has two primary advantages. It is transparent, in that once the connection is made, no additional processing is required by the sending or receiving units. The second advantage is that during the data transfer phase, routing, flow control, and error control are avoided. This allows for simplicity in software. (Stallings, W., 1992, p. 28)

A key disadvantage of circuit switching is the inefficient use of lines (trunks). Once the circuit is established, the line is not available for other users. These users receive a busy signal when trying to access the line.

b. Packet Switching

Packet switching transfer mode partially evolved as a result of the inefficient use of lines in circuit switching. As users discovered the advantages of transmitting information over telephone lines, data communications grew tremendously. The circuit switching technology alone could not efficiently meet the growing bandwidth demand. Telecommunications experts invented a transfer mode (packet switching) that allowed the sharing of bandwidth and included store and forward schemes to accommodate congestion or busy signals between nodes.

Packet switching uses a method known as packetizing to disassemble messages into multiple packets. Each packet contains a header for addressing, and error control. The header information allows the packets to take various paths to reach their destination. At the destination, the packets are sequenced, depacketized, and the message is reformatted to be readable by the receiver(s).

The disassembly and reassembly of the message requires more time. As a result, this transfer method is not efficient for the transmission of time sensitive information (voice and video). However, it does allow the use of shared bandwidth (packets taking various path to reach the destination). This makes packet switching suitable for bursty traffic such as data.

c. *Frame Relay*

Frame relay is a form of fast packet switching and its concepts are similar to "regular" packet switching. However, frame relay uses faster transmission facilities. No addressing, flow control, or error control is used. The data is packetized into variable sizes. Before any data is transmitted, a connection is established, a permanent virtual circuit is created, and all the packets travel along this one path to the destination. There is no need for sequencing because the packets arrive at the destination in the same order that they left the origin. Once all the packets have reached the destination, the circuit is terminated and is available for use by other parties.

d. *ATM*

ATM (also called cell relay) is another form of fast packet switching. Unlike other switching technologies, ATM relay uses fixed sized packets instead of variable sized packets. ATM takes the advantages of circuit switching and packet switching, and combines them to maximize efficiency, transmission speed, and throughput (Luce, C. A., 1994, p. 26). Circuit switching establishes permanent circuits before data is transmitted. ATM sets up virtual circuits using virtual path identifiers and virtual channel identifiers. These circuits remain intact for the duration of the connection and each cell uses this path to reach the destination. Similar to frame relay, where the bandwidth is shared, other users can use the virtual path when it is idle and awaiting a response from either the sender or the receiver which established the path originally.

3. Driving Factors behind ATM

ATM is an emerging technology as a result of four factors (ATM Forum, 1994). First, ATM has grown out of a need for a worldwide standard to allow interoperability of information, regardless of the "end-system" or type of information. It is driven by international consensus instead of one particular manufacturer, or a group of vendors. Second, ATM is a technology that can be used in a LAN, metropolitan area network (MAN), backbone network (BN), or WAN environment. As users requirements to expand from a LAN to a WAN, even globally, ATM can be used to accommodate the users'

needs, and the users networking capabilities will not be the limiting factors. Third, ATM supports various types of information (voice, data, video). It is the only standard designed to support the simultaneous transmission of voice, data, and video, as shown in Figure 2.1. Lastly, ATM allows for the transmission of information at various speeds, ranging from a few Mbps to several gigabits per second (Gbps).

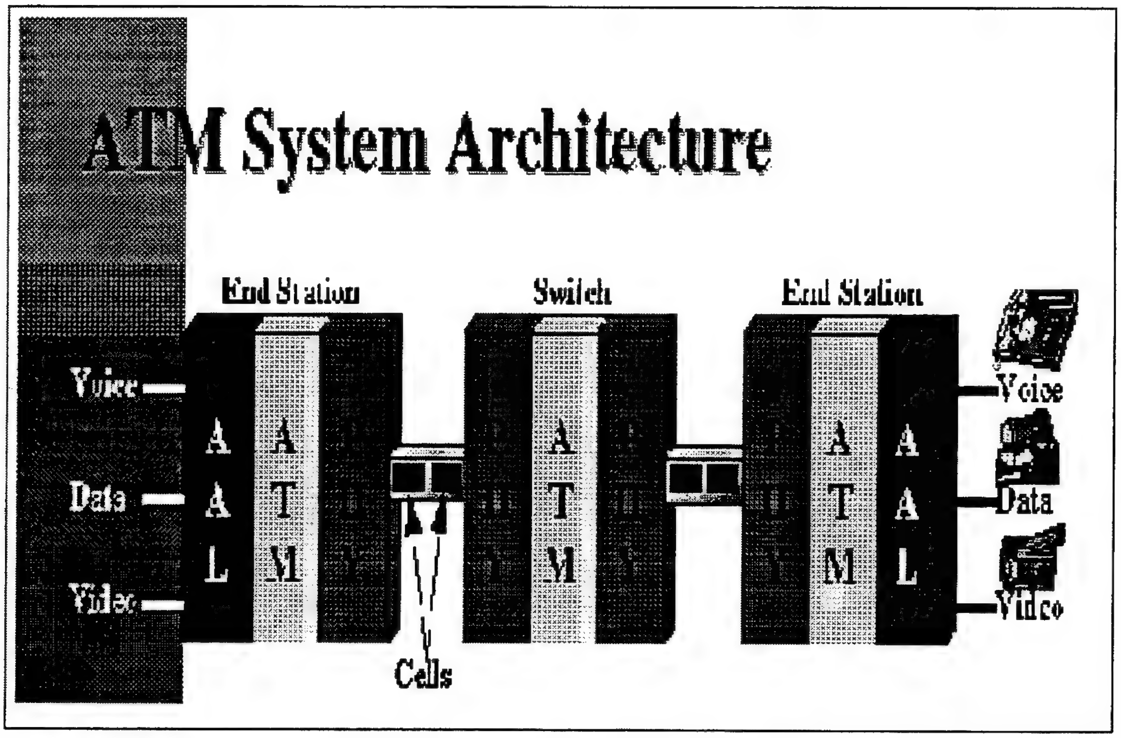

Figure 2:1 ATM System Architecture (ATM Forum, 1994)

4. Benefits of ATM

Along with the ability to simultaneously transmit voice, data, and video, ATM has several other key benefits that makes it appealing to users. These benefits, discussed below, also contribute to ATM's capability and power.

a. Simplification of Network Management

Because ATM can span from a LAN to a WAN, it simplifies network management. Network managers can be trained on one set of tools or technology to

manage an ATM LAN, MAN, BN, or WAN. As a result training time and cost are reduced.

b. Compatibility with Current Cable Plant

ATM is not designed for a specific type of physical transport. It can be transported over twisted pair, coax, and fiber. This makes it compatible with existing network cabling plant, thereby alleviating the need to replace existing cabling with ATM congruous cabling. There are some unresolved issues regarding ATM use over satellites. These issues pertain to the effect of satellite delays on data and the issues of congestion control and error correction required for reliable transfer of data (ATM Forum, 1994).

c. Incremental Migration Capability

In order to use ATM in an existing network, one does not have to wait until the entire network has been upgraded to an ATM network. Instead, one can gain the benefits of ATM incrementally by upgrading portions of the network based on new application requirements and business needs.

d. Long Architectural Lifetime

ATM is designed to be flexible and scaleable in geographic distance, the number of users, and access and trunk bandwidths. ATM can be used locally, in a metropolitan area, transcontinentally, or even globally. The maximum number of ATM user addresses far exceeds FDDI's (500 for one ring, 1,000 for both rings). As mentioned earlier, ATM speeds are flexible. They can range from a few Mbps to several Gbps.

B. ATM PRINCIPLES

This section provides a general overview of ATM and how it works.

1. ATM Cell

As mentioned in the previous section, ATM uses fixed length cells. Figure 2.2 depicts a generic view of the cell format; each cell contain 53 bytes; the first five bytes consist of header information, and the remaining 48 bytes is data. The primary function of

the header is to act as the addressing mechanism. The data field holds the actual information.

Header 5 Bytes	Data 48 Bytes

Figure 2.2 ATM Cell Format

Figure 2.3 provides a detail format of the ATM cell. The header section comprises of GFC, VPI, VCI, PTI, CLP, and HEC. The VPI, VCI, CLP, and HEC will be discussed in depth later. The GFC is used for user network interface (UNI), workstation-to-ATM-switch connections. The GFC does not exist in network-network interface (NNI), ATM-switch-to-ATM-switch connections. A larger VPI field is used for trunking in NNI connections.

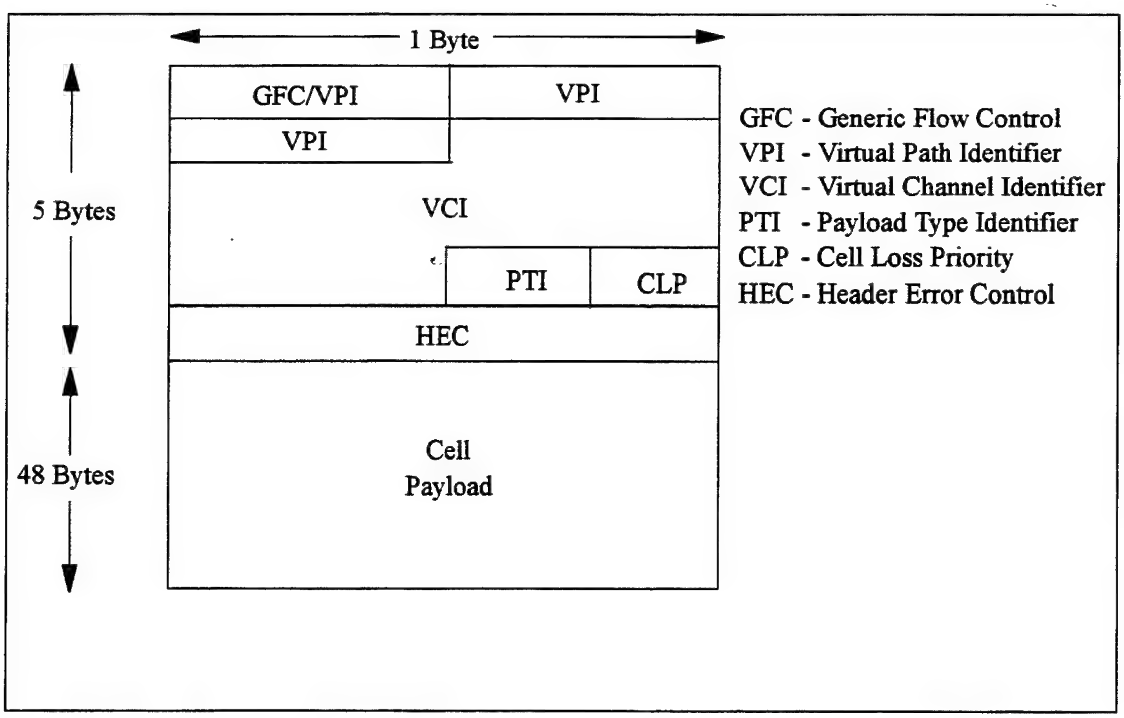

Figure 2.3 Detail ATM Cell Format

2. ATM and the Open System Interconnection (OSI) Model

The OSI model is used with tremendous success to model communication systems. The same logical hierarchical architecture used in OSI is used for the ATM Broadband Integrated Service Data Network (B-ISDN) network (de Prycker, M., 1993, p. 111). Figure 2.4 shows the ATM hierarchy and the OSI model (Luce, C. A., 1994, p. 30). The ATM physical layer is similar to the physical layer of the OSI model. The ATM layer can be considered as equivalent to the data link layer of the OSI model. The ATM adaptation layer also performs functions of both the data link layer; it is capable of performing a few functions of the presentation, session, transport, and the network layers. Figure 2.5, on the following page, illustrates ATM in a layered architectured fashion, and provides a general depiction of how ATM works. Subsections 3, 4, and 5 discuss the Physical Layer, the ATM Layer, and the ATM Adaptation Layer.

ATM B-ISDN Protocol Layers	OSI ISO Reference Model
Application Layer	Application Layer
Higher Layer	Presentation, Session, Transport/ Network Layers
ATM Adaption Layer (AAL) Convergence Sublayer Segmentation & Reassembly Sublayer	
ATM Layer	Data Link Layer
Physical Layer Transmission Convergence Sublayer and Physical Medium Dependent Sublayer	Physical Layer

Figure 2.4 ATM/B-ISDN Model and OSI Model

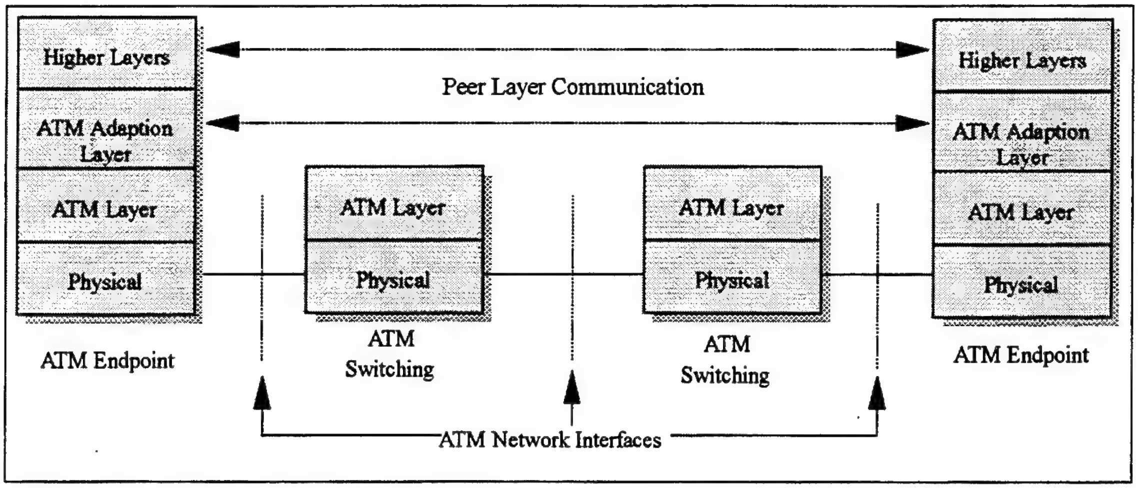

Figure 2.5 ATM Layered Architecture

3. ATM Physical Layer

a. Sublayers

The physical layer contains two sublayers: the Physical Medium (PM) sublayer and the Transmission Convergence (TC) sublayer. The PM supports pure medium dependent bit functions. It is responsible for the correct transmission and reception of bits on the appropriate physical medium. The TC converts the ATM cell stream into bits to be transported over the physical medium. This sublayer performs five functions (de Prycker, M., 1993, p. 113):

- Cell rate decoupling to adapt rate of valid ATM cells to the payload capacity of the system.
- Generation of the HEC syndrome of each cell at the transmitter, and its verification at the receiver.
- Cell delineation to allow for recovery of cells at the destination.
- Transmission frame adaptation.
- Generation and recovery of transmission frames.

b. Error Control

ATM uses no link-by-link error control. The two end nodes on any connection provide the control at the physical layer (Luce, C. A., 1994, p. 31). The header designates eight bits for error detection and error correction. The receiver has a correction mode and a detection mode. In the correction mode, cells with a single bit error are corrected. In the detection mode, cells with two or more bit error are discarded, and require retransmission. Figure 2.6 depicts how error correction is performed at the receiver (de Prycker, M., 1993, p. 123).

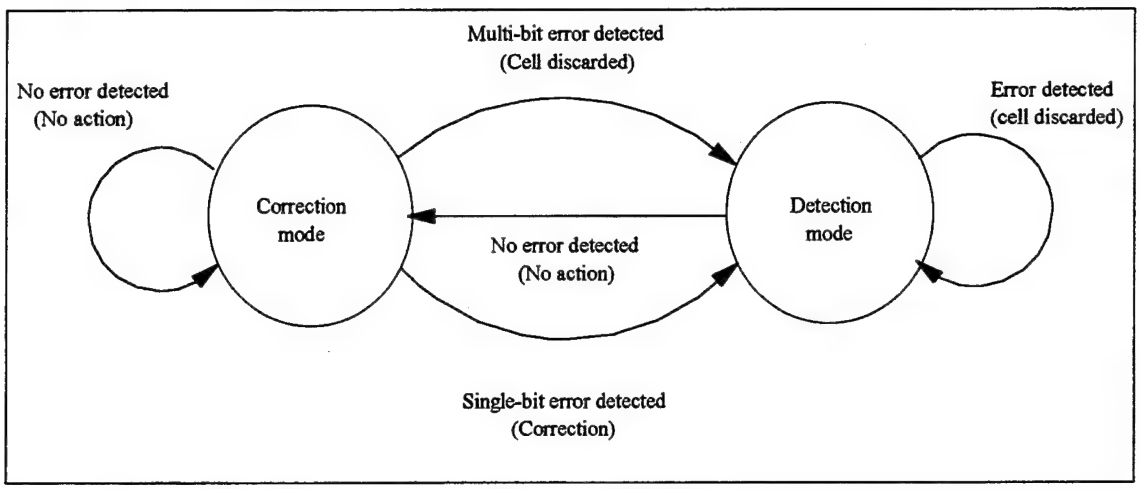

Figure 2.6 Dual Mode Operation of the HEC Algorithm

4. ATM Layer

The ATM Layer is completely independent of the physical medium used to transport ATM cells. As a result, it is also fully independent of the physical layer. The ATM layer performs the following main functions (de Prycker, M. 1993, p. 115):

- Multiplexing and demultiplexing of cells of different connections (identified by different VCI and/or VPI values) into a single cell stream on the physical layer.
- Translating the cell identifier, which is required in most cases when switching a cell from one physical link to another, in an ATM switch or cross connect.

- Providing the user a virtual channel connection or virtual path connection with one quality of service class, out of a number of classes supported by the network.
- Managing layer types using information in the cell header.
- Extracting (adding) the cell header before (after) the cell is delivered to (from) the adaptation layer.
- Implementing a flow control mechanism on the user-network interface.

5. ATM Adaptation Layer

The ATM Adaptation Layer (AAL) enhances the services provided by the ATM layer to a level required by the next higher layer. It is subdivided into two sublayers: the segmentation and reassembly sublayer (SAR), and the convergence sublayer (CS). The primary function of the SAR sublayer is segmentation of the higher layer information into a size suitable for the payload of the consecutive ATM cells of a virtual connection, and the inverse operation, reassembly of the contents of the cells of virtual connection into data units to be delivered to the higher layer. The convergence sublayer performs functions like message identification, time/clock recovery, etc. (de Prycker, 1993, p. 115)

The AAL provides the user the capability to send various types of information over an ATM network at either constant or variable bit rates. The end-to-end connection established to transport the information can be connection or connectionless oriented. The information can be either voice, data, video, image, or even a combination of these in multi-media applications. The below table provides the classes of services offered and the protocol support by ATM B-ISDN.

Class:	A	B	C	D
Example	Voice/Video	Packet Video	Data (IP, X.25)	Data (SMDS)
Connection Mode	Connection-Oriented (C.O.)	C.O.	C.O.	Connectionless
Bit Rate	Constant	Variable	Variable	Variable
ATM Adaption Layer	AAL-1	AAL-2	AAL-3/4 AAL-5	AAL-3/4

Table 2.1 ATM B-ISDN Classes of Services

6. ATM Connections

Before information traverses an ATM network, a connection must be established. The connection setup prior to the sending and receiving of information makes ATM a connection oriented network. All information at the sending node will use the same "pipe" to reach the receiving node. After the receiving node retrieves all the information associated with the transmission, the connection is terminated.

a. Virtual Channels

The "pipe" or logical connection which the information traverses is the virtual channel. These channels are identified by the VCI in the header of each ATM cell. The VCI field has 16 bits. Theoretically, this allows up to 2^{16} or 65,536 virtual channels in physical connections. Each channel can be assigned various speeds (kilobits per second to gigabits per second).

b. Virtual Paths

When virtual channels have the same origin and destination, they can be consolidated into virtual paths. These paths are defined by the VPI in the header of each ATM cell. The VPI field is 8 bits for UNIs and 12 bits for NNIs. The additional four bits replace the GFC bits which are not required for NNIs. Figure 2.7 depicts the relationship between VCIs and VPIs (de Prycker, M., 1993, p. 86). The bold lines between the ATM

nodes represents the physical connection and the non-bold lines depicts the logical connection (VCIs and VPIs) which are established and torndown within the physical connections.

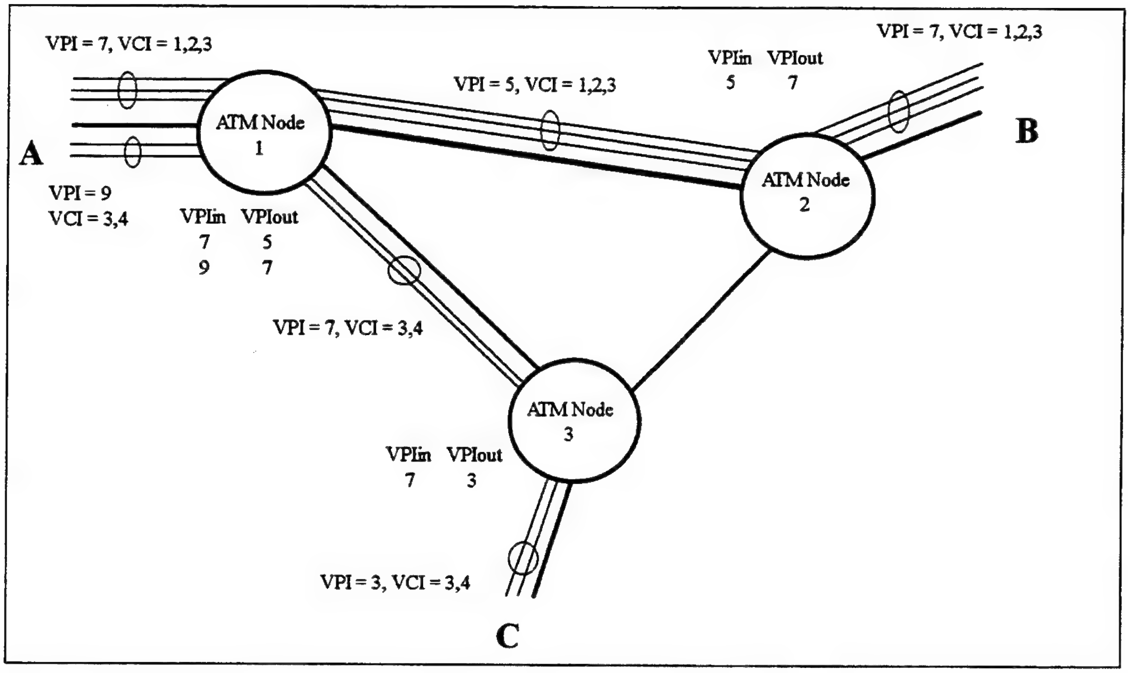

Figure 2.7 ATM Network using Virtual Channels and Virtual Paths

In Figure 2.7, a virtual path is established between subscriber A and subscriber C, transporting two individual connections, each with a separate VCI. Note that the VCI values used (3 and 4 in the example) are NOT translated in the nodes, which are only switching on the VPI field. In addition, a virtual path between A and B is semi-permanently established, using VCI values 1, 2, and 3. Another interesting point is that the link between A and node 1, uses 3 as the VCI value twice. This creates no problems, since the different VPI values allow the two endpoints (A and node 1) to discriminate between the two virtual connections. (de Prycker, M., 1993, p. 86)

C. ATM LAN EMULATION

1. Overview

When the 10 Mbps Ethernet LAN standard was finalized over 15 years ago, one would have never believed that 10 Mbps would not be capable of efficiently handling today's applications and a large workgroup of users. Though the 16 Mbps Token-Ring technology is faster than 10 Mbps Ethernet networks, the Token-Ring networks still is not capable of efficiently meeting today's, as well as future, application demands. Users are now competing more and more for computing resources and are bringing network (LANs) to a crawl. As a result, thousands of users have lost confidence with existing "customer premise" networks. Many have resulted to loading application software on their own computer to reduce the time required to bring up an application such as WordPerfect, Lotus 123, Excel, and Paradox.

Because of the demand for more bandwidth to the desktop, and the development of multi-media applications, industry is developing new technology to satisfy user needs. Some technologies are based on traditional shared medium (FDDI, DQDB, Fast Ethernet), and others are based upon a switched point-to-point topology (Switched Ethernet, ATM) (Newman, P., 1993, p. 44).

A shared medium design restricts the total capacity available to the LAN at the speed of the shared medium. This circumscription gets expensive at high speeds. Also, as more users are added to the shared medium, the capacity must be divided between the users. For example, if a 10 Mbps Ethernet LAN supported 25 users, and all 25 users accessed the network simultaneously, the average throughput per user would be 400 kilobits per second (Kbps). ATM networks do not have this limitation; ATM can scale from small multiplexers to very large switches in both aggregate capacity and number of access ports. It can accommodate access ports from low speeds to very high speeds. ATM is also designed to handle multimedia traffic. Due to these capabilities, ATM is heavily considered as a technology that should support traditional LAN services. (Newman, P., 1993, p. 44)

To make ATM to the desktop more appealing to users, industry had to consider the installed base of existing LAN protocols and applications. The majority of installed protocol stacks rely on facilities provided by today's LANs. In order to use the current base of existing LAN applications, ATM must use a process known as LAN Emulation (LANE). In this process, ATM emulates services of existing LANs on an ATM network without the need of any change in the ATM terminal equipment's interface to the media access control (MAC) layer. (Kavak, N., 1995, p. 28)

The LANE protocol emulates a LAN on top of an ATM network. The protocol defines the mechanisms to emulate either an IEEE 802.3 Ethernet or an 802.5 Token Ring LAN. Specifically, the LANE protocol defines a service interface for higher layer (that is, network layer) protocols, which is identical to that of the existing LANs, and the data sent across the ATM network are encapsulated in the appropriate LAN MAC packet format (Alles, A., 1995, p. 24). This does imply that any attempt is made to emulate actual MAC protocol of the specific LAN concerned (i.e., CSMA/CD for Ethernet or token passing for 802.5).

Figure 2.8 provides an illustration of the LANE protocol architecture (Alles, A., 1994, p. 25).

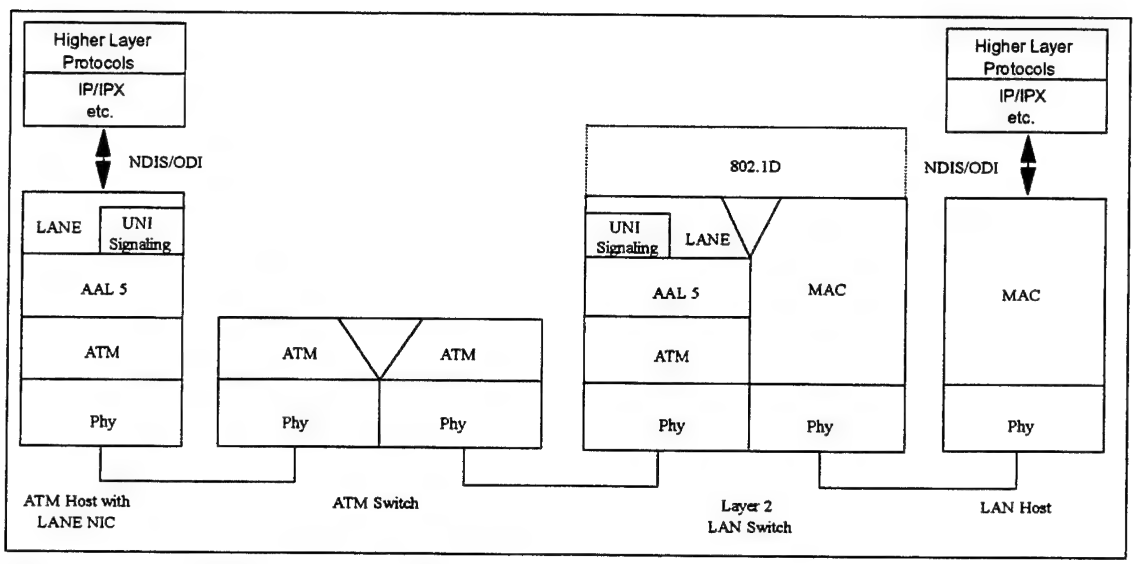

Figure 2.8 LANE Protocol Architecture

The current LANE protocol does not define a separate encapsulation for FDDI. FDDI packets must be mapped into either Ethernet or Token-Ring emulated LANs, using existing translational bridging techniques. Fast Ethernet (100Base-T) and 802.12 (100VG-AnyLAN) can both be mapped unchanged into either the Ethernet or Token-Ring LANE formats and procedures, as appropriate, since they use the same packet formats. (Alles, A., 1995, p. 24)

2. Connectionless Service Implementation

ATM switches use connection oriented services to pass information. However, current LAN technologies use connectionless services as a method of communicating. To address this difference, ATM LANs use connectionless servers (CLSFs) to offer connectionless service at the MAC layer.

In its simplest form, a CLSF is a packet switch attached to an ATM switch. All virtual channels carrying traffic that requires a connectionless switching service is directed by the ATM switch to the CLSF. The CLSF are connected together with virtual paths through the ATM switch to form a "virtual\overlay network." Figure 2.9 illustrate the implementation of connectionless data service. (Newman, P. "ATM Local Area Networks," 1994, p. 95)

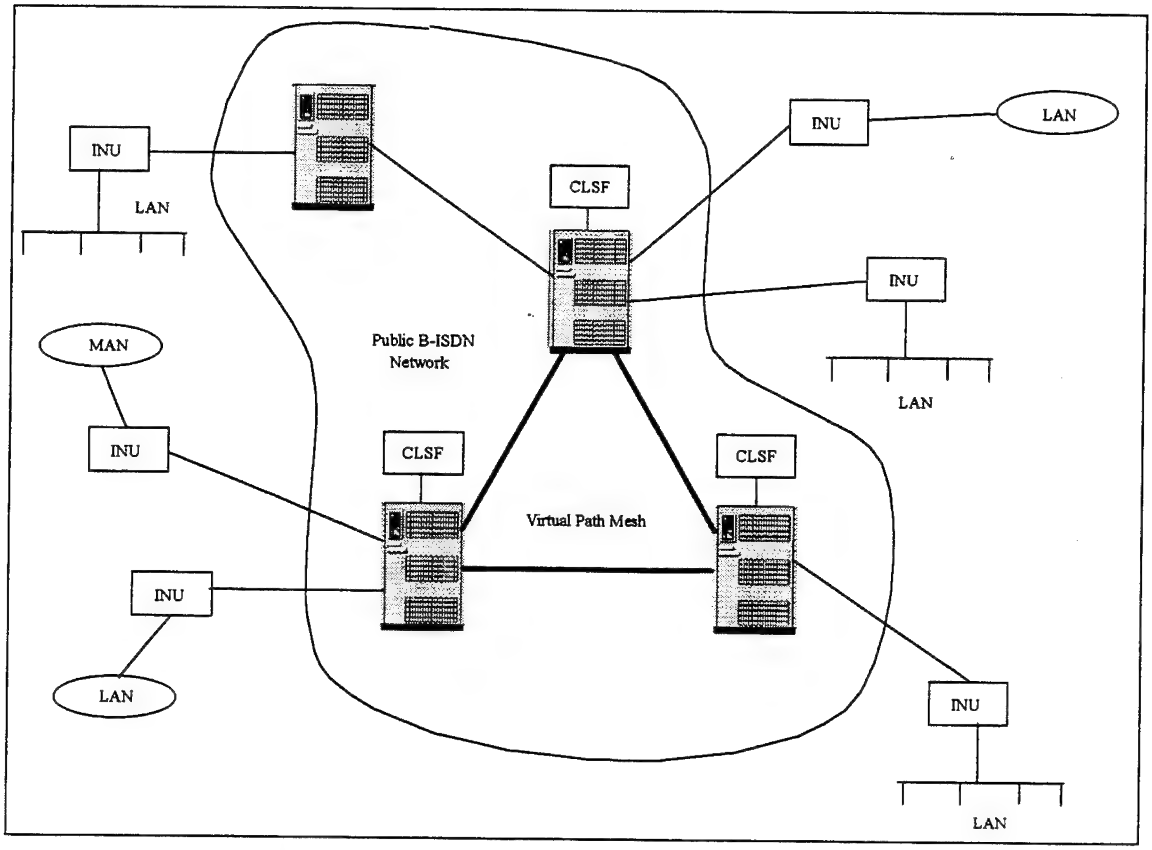

Figure 2.9 B-ISDN Connectionless Data Service Implementation

3. Emulated LAN Components

The LANE protocol defines the operation of a single emulated system LAN (ELAN). Multiple ELANs may coexist simultaneously on a single ATM network since ATM connections do not collide. A single ELAN emulates either Ethernet or Token Ring, and consists of the following entities: (Alles, A., 1995, p. 26)

- LAN Emulation Client (LEC): A LEC is the entity in an end system that performs data forwarding, address resolution, and other control functions for a single end-system within a single ELAN. A LEC also provides a standard LAN service interface to any higher layer entity that interfaces to the LEC. An ATM NIC or LAN switch interfacing to an ELAN supports a single LEC for each ELAN to which they are connected. An end-system that connects to multiple ELANs will have one LEC per ELAN. Each LEC is identified by a unique ATM address, and is associated with one or more MAC addresses reachable

through that ATM address. In the case of an ATM NIC, for instance, the LEC may be associated with only a single MAC address, while in the case of a LAN switch, the LEC would be associated with all the MAC addresses reachable through the ports of that LAN switch which are assigned to the particular ELAN.

- LAN Emulation Server (LES): The LES implements the control function for a particular ELAN. There is only one logical LES per ELAN, and to belong to a particular ELAN means to have a control relationship with that ELAN's particular LES. Each LES is identified by a unique ATM address.

- Broadcast and Unknown Server (BUS): The BUS is a multicast server that is used to flood unknown destination address traffic, and forward multicast and broadcast traffic to clients within a particular ELAN. Each LEC is associated with only a single BUS per ELAN, but there may be multiple BUSs within a particular ELAN that communicate and coordinate in some vendor-specific manner. The BUS to which a LEC connects is associated with the broadcast MAC address. In the LES, this is associated with the broadcast MAC address ("all ones"), and this mapping is normally configured into the LES.

- LAN Emulation Configuration Server (LECS): The LECS is an entity that assigns individual LANE clients to particular ELANs by directing them to the LES that correspond to the ELAN. Locally, there is one LECS per administrative domain, and this serves all ELANs within that domain.

Though the current LANE specification define two types of ELAN, (Ethernet and Token-Ring), the specification does not permit direct connectivity between an Ethernet ELAN and a Token-Ring ELAN. The two ELANs must interconnect through an ATM router which acts as a client on each ELAN (Alles, A., 1995, p.26).

Another important note to mention is that the aforementioned server components can run on any device with ATM connectivity. However, for the purpose of reliability and performance, most vendors will more than likely implement the server components on

ATM switches or routers, rather than a workstation or host. An illustration of LANE protocol interfaces are provided in Figure 2.10.

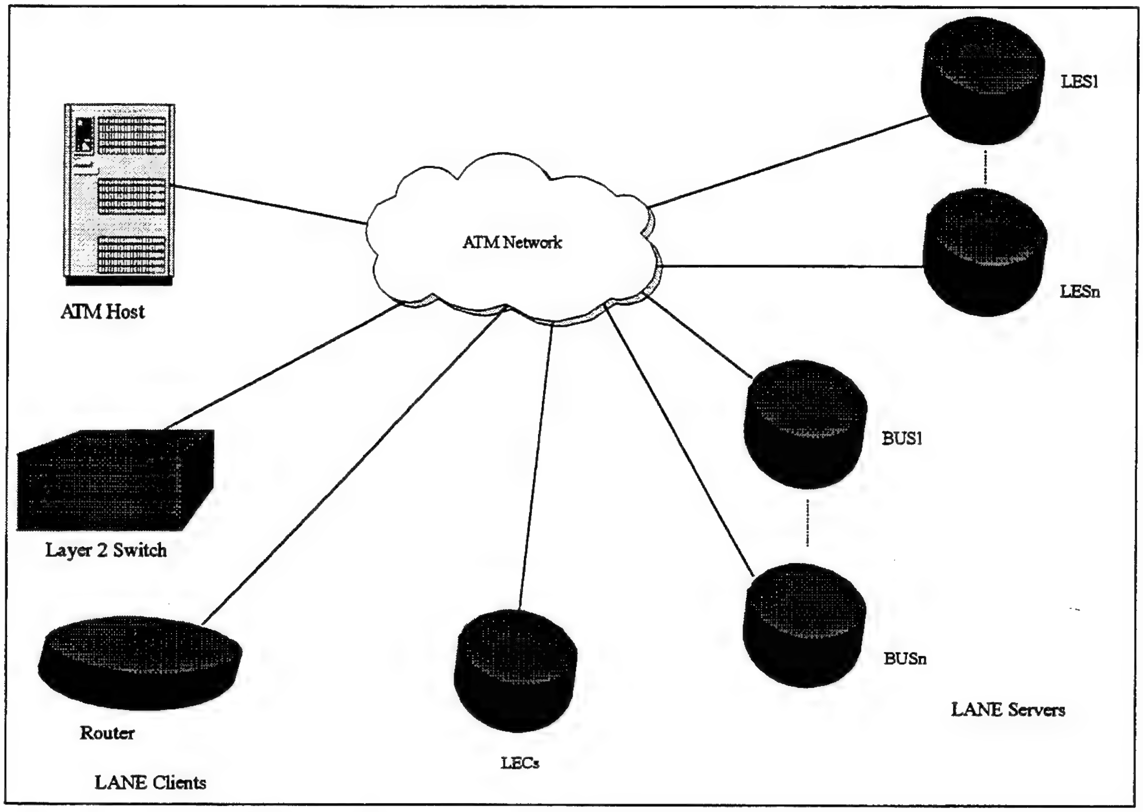

Figure 2.10 LANE Protocol Interfaces

4. Traffic Management

As with an ATM WAN, ATM LANs will more than likely have to provide two classes of traffic, guaranteed and best-effort. Guaranteed traffic is traffic (e.g., video, voice) for which a certain quality of service (QoS) (cell delay, cell delay variation, cell priority, cell loss, type of information that will be transmitted, speed) is provided by the network. The guarantee establishes a contract between the traffic source and the network (Newman, P., "Traffic Management for ATM Local Area Networks," 1994, p. 45). Before the contract is finalized, and a connection is set up between the origin and the intended destination, the network will query itself (traffic, available bandwidth) to

determine if it can offer the requested QoS. The network will also monitor the traffic to ensure that the transmission stays within the contracted parameters.

The network ,or switching hardware, must ensure that QoS for guaranteed traffic is not adversely affected by best-effort traffic. This can be accomplish by creating two buffers in the switch hardware, one for guaranteed traffic and the other for best-effort traffic. The queue service algorithm always serves the guaranteed traffic in preference to the best-effort traffic. Figure 2.11 provides a general illustration of the two buffers (Newman, P., "Traffic Management for ATM Local Area Networks," 1994, p. 45).

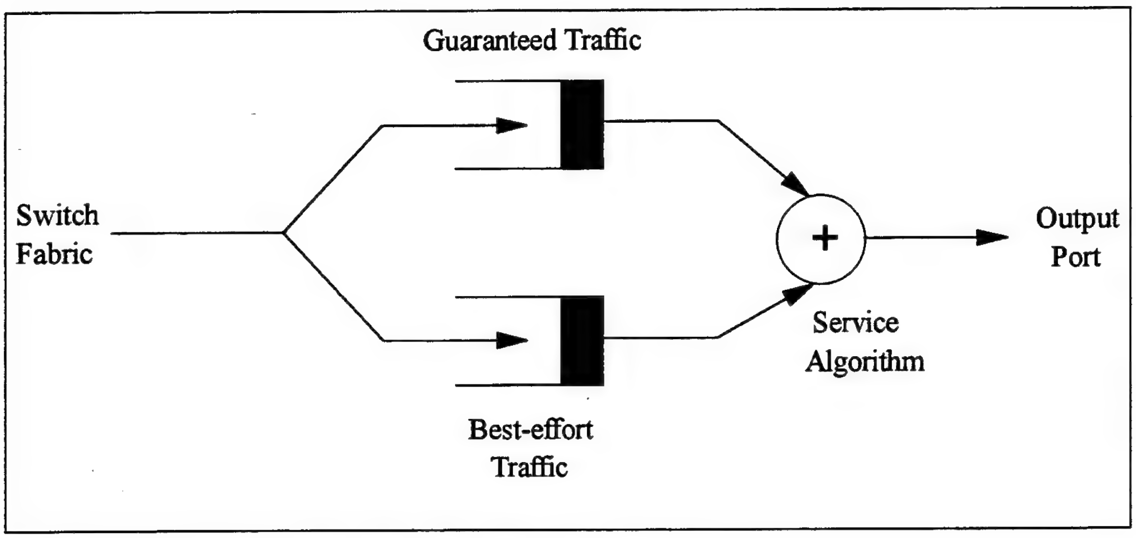

Figure 2.11 Output Buffer with Two Classes of Traffic

In an IEEE 802 LAN, the shared medium provides the shared bandwidth and the MAC protocol is the arbitration mechanism by which the bandwidth is shared between the contending users. In an ATM switch, each output port is a pool of bandwidth that need to be shared dynamically between all connections currently sending best-effort traffic across it. Some congestion control scheme must be implemented in an ATM LAN to support the statistical sharing of bandwidth between competing stations without prior bandwidth reservation. To date, three approaches are available for congestion control: over-provision in terms of bandwidth or buffers, loss mechanisms, and delay mechanisms. (Newman, P. "ATM Local Area Networks," 1994, p. 95)

Over-provision has its congestion limitations in both bandwidth and buffering. Bandwidth is fairly obvious: if bandwidth is overly allocated, then this reduces the capability of the ATM switch to provide services to an abundance of simultaneous users. Regarding buffering, if the delay through the buffer exceeds the retransmission time-out of the higher layer protocols, more retransmission traffic will be introduced to the network while the network is congested.

Loss mechanisms discard cells during periods of congestion. However, this leads to a problem of creating more traffic or congestion on the network. Each discarded cell may belong to different packets. As a result, each packet must be retransmitted and bandwidth is wasted by the onward transmission of the remaining cells from corrupted packets. Various approaches have been explored to address this problem. One in particular is the use of cell loss priority. The ATM switch would discard low priority cells rather than high priority cells. This approach is very difficult to implement. Methods cannot be visualized as to how data traffic could be coded into two loss priorities at the MAC sublayer.

Delay mechanisms use negative feedback from the point of congestion back towards the source to reduce the traffic entering the network. Forward explicit congestion notification (FECN) sends a congestion indication along the forward data path to the destination. The destination then takes some action to cause the source to reduce its transmission rate. Backward explicit congestion notification (BECN) sends the congestion indication directly back to the source along a return path. On receipt of this indication the source reduces its transmission rate directly. BECN can respond to congestion more rapidly than FECN but requires congestion notification cells to be inserted into the network. On the other hand, FECN can simply mark a bit in the cell header as it passes through the point of congestion. Other delay mechanisms have been proposed that use credit or backpressure on each virtual connection, on a link-by-link basis between switches and ultimately back to the source. This approach offers much tighter flow control, but is considerably more complex to implement. (Newman, P. "ATM Local Area Networks," 1994, p. 96)

5. LANE and Virtual LANs

Vendors use LANE to provide virtual LAN services on an ATM network. The virtual LANs are implemented on switched internets using a combination of LAN switching (bridging), ATM end systems (servers, using ATM NICs), and routers with ATM interfaces ("ATM routers"). These devices are all connected to an ELAN. The ELAN looks and functions like a typical LAN except for the bandwidth as far as either end systems attached to the LAN ports on the LAN switches, or the higher layer protocols operating within the ATM hosts or routers are concerned (Alles, A., 1995, p. 31).

Implementing a virtual LAN using LANE has many advantages; one in particular is network management. Through network management, and the use of mechanisms such as the LECs, the network administrator can set up several ELANs across a single ATM backbone, and then assign LAN switch ports or ATM hosts to the different ELANs, independent of the physical location of the devices (Alles, A., 1995, p. 31). This process removes the physical location limitation of current LANs. As a result, the physical location of the devices no longer determines the LAN segment to which the devices can be connected.

Virtual LANs also give the network administrator the ability to change or reconfigure virtual networks without changing the cabling plantas the organization work flows or processes change. This helps reduce the cost of moving or adding personnel.

Though virtual LANs have great benefits, there is also a downside. Because LANE is a LAN bridging standard, ELANs are susceptible to broadcast storms. This tends to limit ELANs to small workgroup. As a result, large networks are likely to support a large number of virtual LANs (ELANs).

An illustration of connectivity between ELANs are provided in the Figure 2.12.

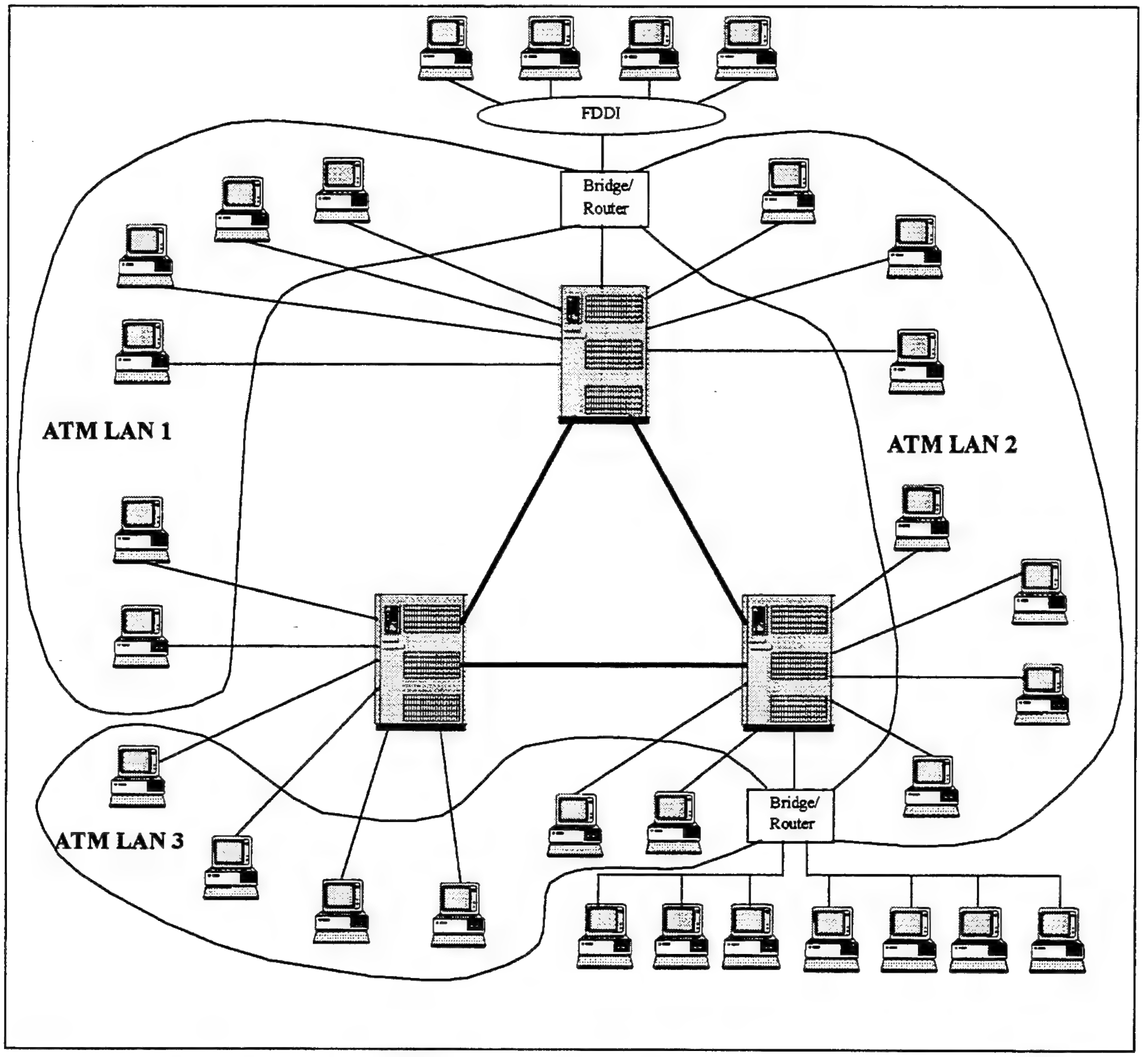

Figure 2.12 ATM LAN Segments (Virtual LANs)

D. ATM STANDARDIZATION PROCESS

Prior to October 1991, ATM or B-ISDN standards were established by standard making bodies such as the International Telecommunications Union (ITU) (formerly the International Telegraph and Telephone Consultative Committee (CCITT)), and the American National Standards Institute (ANSI). These organization primarily focused on future public B-ISDN networks and often took years to finalize standards. Manufacturers became concerned that high bandwidths requirements for end users (customer premises equipment (CPE) and private switching equipment) would become more prevalent than the need for high bandwidth for public networks and wanted to expedite the standards making

process. As a result, these manufacturers (CPE vendors, public equipment vendors), telecommunication operators, and users formed the ATM Forum which is the "premier" ATM standards body.

The ATM Forum has more than 700 member companies, and it has five committees: the Technical Committee, three Marketing Committees for North America, Europe and Asia-Pacific, and an Enterprise Network Roundtable.

The Technical Committee is a single worldwide committee and primarily focus on promoting a single set of specifications to ensure interoperability between all vendors as ATM products and services become available (http:/www.atmforum.com/atmforum/ atm_introduction.html, p.1). This committee has done work on User-Network Interface, Data Exchange Interface (defines how existing network equipment such as bridges, routers, and hubs can act as front-end processors to an ATM network), LAN Emulation, and Broadband Inter-Carrier Interface specifications. The Technical Committee is also working on key areas such as traffic management, signaling, physical interfaces, network management, service aspects and applications, and testing. Appendix A is a Technical Committee update which provides a status report of current work items as of December 1995 (Hold, D. F., 1995, p.11).

The ATM Market Awareness and Education Committee (MA&E) functions as the public affairs agencies for the ATM Forum. Their primary focus is to provide marketing and educational services for the understanding and acceptance of ATM technology.

The Enterprise Network Roundtable Committee consists of end-users. This committee interacts on a regular basis with (MA&E) to ensure that ATM technical specifications meet their needs.

E. ATM IMPLEMENTATION

Because ATM is scaleable from a LAN environment to a WAN environment, it can be applied in a WAN, MAN, or LAN. The technology can also be used in all three environments simultaneously, thus creating a "pure" ATM network. The next three sub-subsections discuss ATM networks in WAN, MAN, and LAN environments.

1. ATM WAN

ATM over a WAN provide greater bandwidth over long hauls. It gives the user the capability to transmit data, voice, and video over one ubiquitous network, instead of having three separate networks for voice, data, and video. Figure 2.13 shows the use of ATM in a wide area.

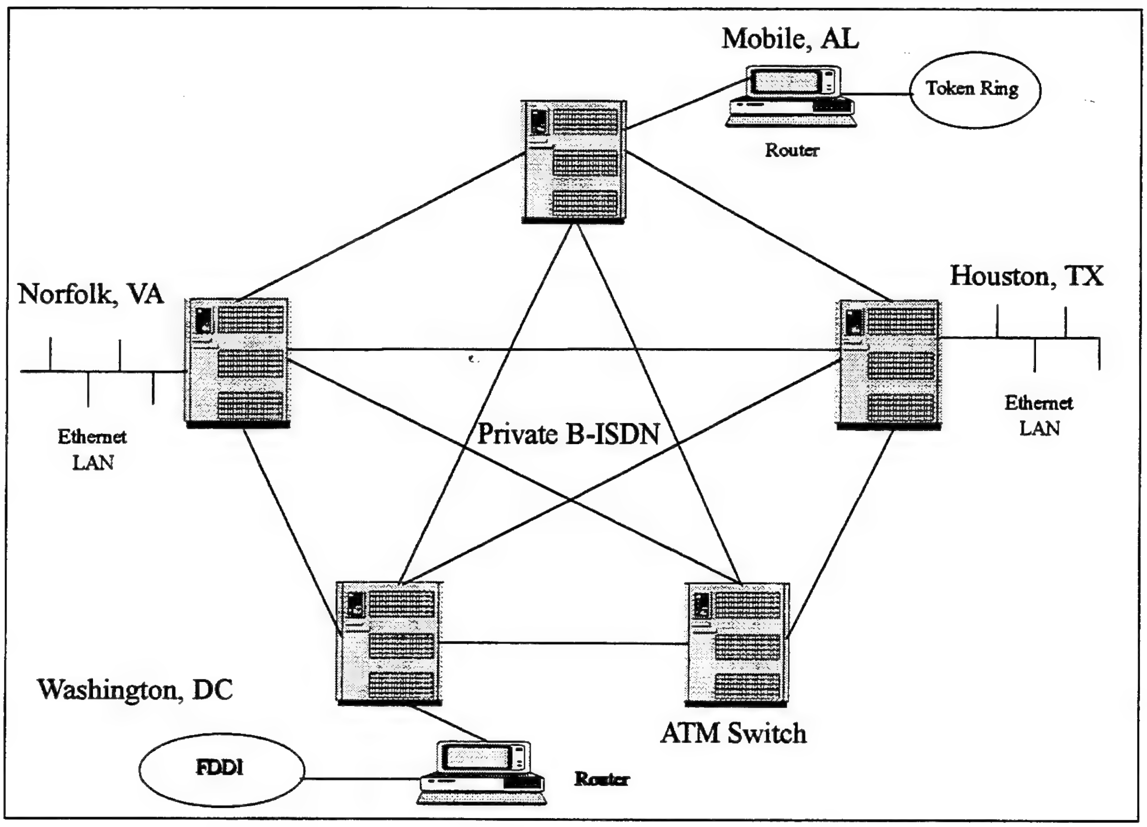

Figure 2.13 ATM WAN

2. ATM MAN

A MAN is a network capable of providing high speed (more than 1 Mbps) switched end-to-end connectivity across distances ranging from 5 to 50 km. This allows a MAN to span an entire university campus, an entire city, or an office park. Like an ATM WAN, an ATM MAN allows the simultaneous carrying of different types of traffic such as data, voice, and video. These characteristics make the MAN complementary to the definition of B-ISDN. (de Prycker, M., 1993, p. 259).

The Advanced Technology Demonstration Network (ATDnet), an ATM MAN, is currently operational in the Washington DC metropolitan area. ATDnet is a high performance networking testbed which is intended to represent a possible future MAN. It uses ATM and Synchronous Optical Network (SONET) technologies to connect six federal Agencies: the Advance Research Project Agency (ARPA), the Defense Information Systems Activity (DISA), the Defense Intelligence Agency (DIA), the National Aeronautics and Space Administration (NASA), the Naval research Laboratory (NRL), and the National Security Agency (NSA).

The ATDnet concept is to interconnect these agencies with high speed fiber optic transmission media, and to overlay these media with SONET and ATM protocols. The initial deployment operated at OC-48 data rates (approximately 2.4 gigibits/second), but is designed to scale upwards to technology-limited data rates. Pair-wise and multiple party research initiatives and experiments are planned over the lifetime of the testbed. Experimental testing of the bitways and a diversity of service and applications experiments are intended to gain insight into the potential of this new performance level (Edicott, D., 1994).

Figure 2.14, on the next page, depicts the testing of the ATM MAN during 1995. Following the installation of the additional pair of fibers, each government site had four-fiber, OC-48 SONET service to the add/drop multiplexer (ADM), a Metropolitan Point of Presence (MPOP). Initially, each on-site MPOP had two OC-3 (155 MBits/sec) service connections to on-premise ATM switches.

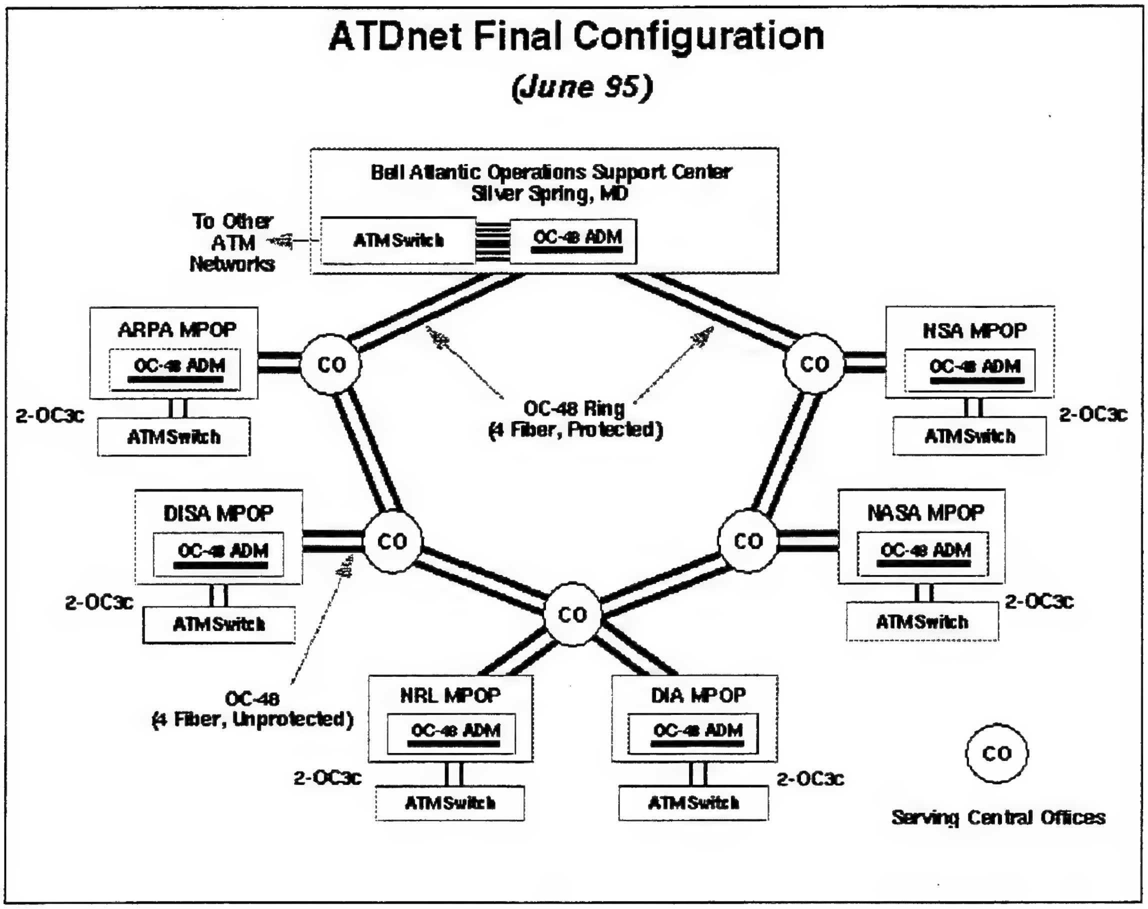

Figure 2.14 June 1995 ATDnet Test Strategy

Each participating agency in the ATDnet is responsible for on-premise routing, and local distribution of ATM and SONET traffic is the individual responsibility of each participating agency (Edicott, D., 1994). Typical configurations may include ATM service to scientific/engineering workstations, databases and file servers, high performance computers, and high resolution, and 3D display devices. Figure 2.15 provides a general idea of the ATM configuration for DISA.

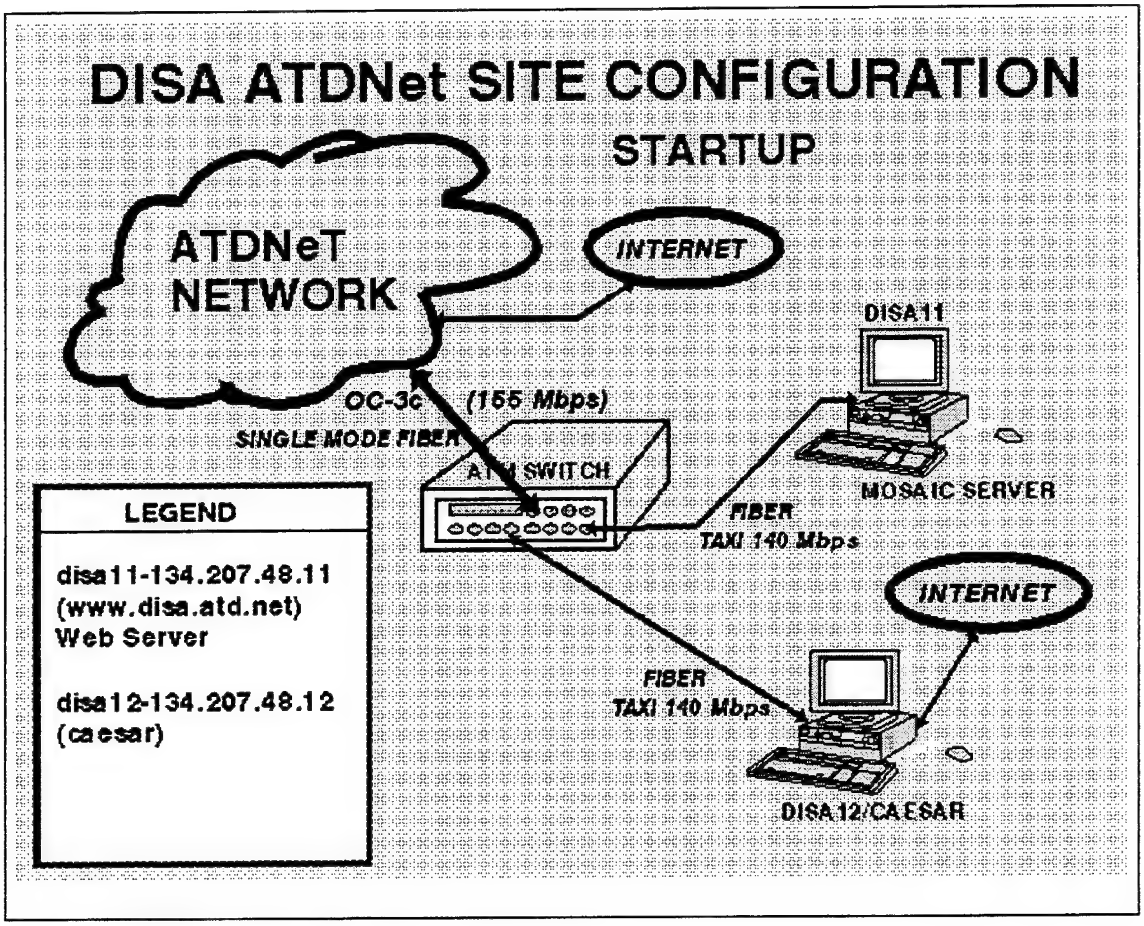

Figure 2.15 DISA ATDnet Site Configuration

3. ATM LAN

Implementing ATM on a LAN will give the user tremendous bandwidth at the desktop. Instead of the bandwidth being shared between the users on the LAN, the vast bandwidth will be dedicated to the user during data transfer. This is accomplished by replacing the shared medium with a centralized switch. By having additional dedicated bandwidth to each workstation or personal computer, users are capable of accessing more powerful applications such as video teleconferencing to the desktop and shared multi-media applications. Figure 2.16 illustrates an ATM LAN.

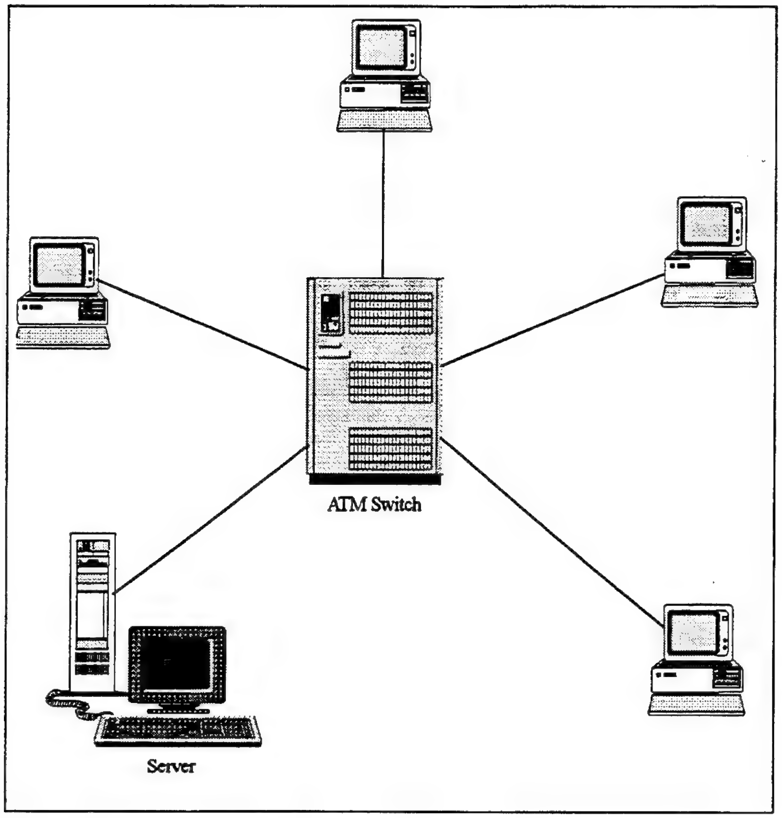

Figure 2.16 ATM LAN

F. CHAPTER SUMMARY

ATM has numerous advantageous over existing networking technologies (frame relay, ISDN, shared media). One in particular is ATM's ability to service different types of information (data, voice, and video). ATM is also scaleable in speed (Mbps to Gbps), and geography (local, metropolitan, and wide areas). Because ATM is scaleable in the local, metropolitan, and wide area, network management is simplified. The same set of tools can be used on the various sizes of the network. This reduces both training cost and time. Another key point in ATM's favor is its ability to dedicate bandwidth to each end-unit, instead of having to share bandwidth like Ethernet and Token-Ring technology. Finally, ATM can run on existing cabling plants (twisted pair, coax, and fiber). This allows end-users the usage of their current cabling plant instead of having to replace it.

III. ATM IMPLEMENTATION ISSUES

A. INTRODUCTION

1. Purpose of Chapter

This chapter discusses implementation issues affecting the ATM technology as a whole. Many of the issues relate to ATM LANs and how they function. Some issues are only applicable to ATM backbones, MANs, and WANs. However, because of their significance, and the possibility of connecting a redesigned Systems Management's laboratory LAN to the Naval Postgraduate School campus backbone, these issues are also discussed.

Because ATM standards are evolving, many implementation issues discussed in this chapter may be resolved by the time this thesis is published.

2. Standardization

Given ATM's capabilities, it alone holds the promise of a single technology supporting high performance data, voice, and video services through the seamless integration of local and wide area networks, including those in the tactical theater of operations.

As with any new technology, risk is a major factor, and this is particular true with ATM. Standards are still evolving, and many manufacturers have been reluctant to wait for concrete specifications. Due to this, many products have been marketed that only have the capability to operate with the manufacturer's, or very few vendors', equipment. Many of these "stove pipe" network products are headed for the orphanage once a real ATM specification set is agreed on, because they will face software incompatibility with many of the high-bandwidth applications that drive the demand for ATM. (Gallagher, S., 1995, p. 40)

Areas in which standards have not been established, or still evolving are LAN emulation, signaling, congestion and flow control, Internet Protocol (IP) over ATM,

firewalls, and AAL compatibility. The subsequent sections of this chapter discuss these issues.

B. LAN EMULATION

1. Problem

As discussed in the previous chapter, the function of the LANE protocol is to emulate a LAN on top of an ATM network. The protocol makes the ATM network behave like an Ethernet or Token-Ring network, even though, the network is running at a much faster bit rate.

The current LANE protocols (Phase 1) specify only the operation of the LAN Emulation User-to-Network Interface (LUNI) between a LEC and the network providing the LANE service. No specifications have been finalized for the functioning of the LAN Emulation Network-to-Network Interface (LNNI). The LNNI operates between the server components within a single ELAN system. The Phase 1 LANE protocols also do not allow for the standard support of multiple LESs or BUSs within an ELAN. As a result, these components are a single point of failure and a potential bottleneck. The interactions between each of the server components in the LANE Phase 1 protocol are currently left unspecified, and will be implemented in a proprietary manner by vendors. (Alles, A., 1995, p. 26)

Figure 3.1 illustrates of the LUNI and LNNI interfaces.

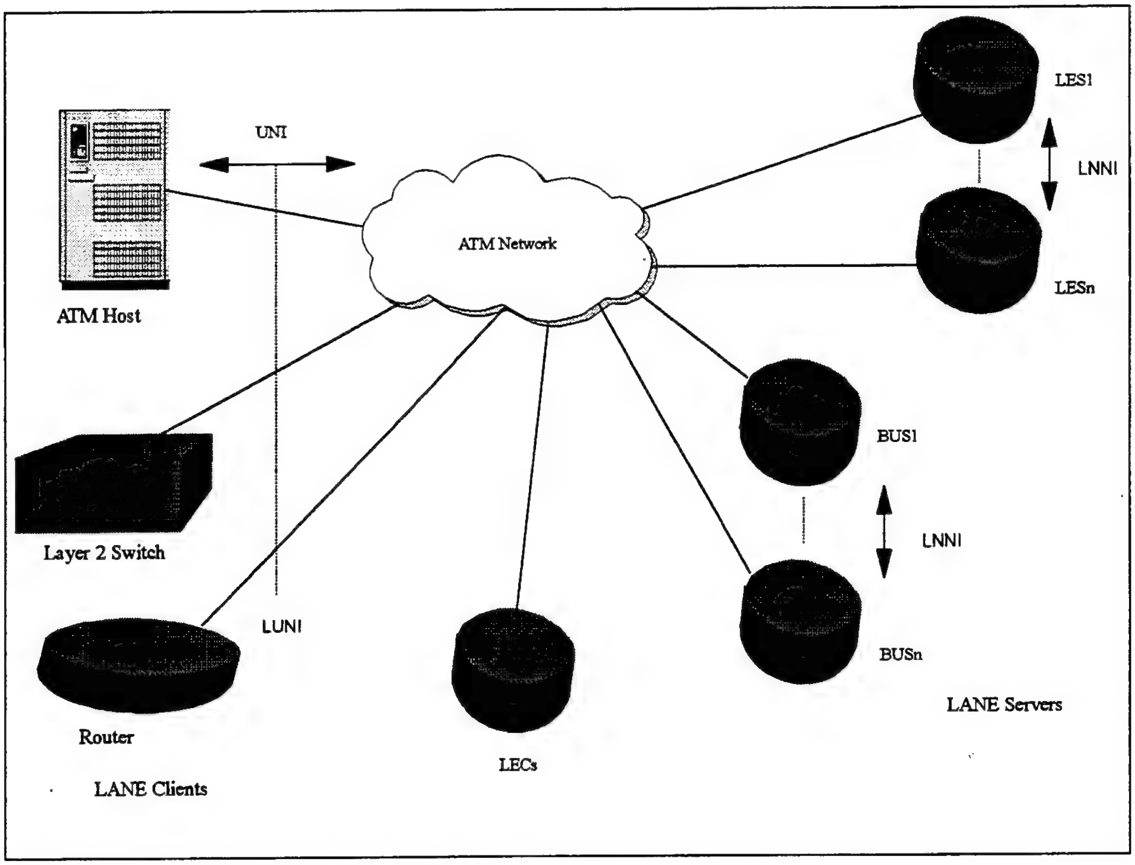

Figure 3.1 LANE Protocol Interfaces

2. Projected Release of LNNI Standard

The ATM Forum is currently working on a Phase 2 LANE protocol. This protocol will specify LNNI protocols to allow for redundant LESs and replicated BUSs. The LNNI protocols will specify open interfaces between the various LANE server entities (LES/LES, LES/LECS, and BUS/BUS). The protocols will also allow for hierarchies of BUSs for greater scalability within ELANs. The projected completion data of the LNNI protocols is 1996.

C. NETWORK MANAGEMENT

1. Overview

Today's network management architectures and tools are not designed to handle the speed and complexity of ATM networks. These management solutions are developed to manage router or time division multiplexing (TDM) based networks, and cannot meet the critical requirements to control and operate an ATM network.

ATM fundamentally changes the landscape of today's networks. The connection-oriented environment, varying classes of services, and higher volume of multiple traffic types differ significantly from yesterday's staticly configured, standalone networks. As a result, ATM networks require a new management model, one which takes these differences into account. (Alexander, P., 1995, p. 47)

2. Problem

With the virtual networking capabilities associated with ATM, the traditional physical and logical network management capabilities are greatly complicated by the addition of voice and video over the same network infrastructure. Thus, the entire network must be perceived as one entity, not as multiple networks. Network managers will no longer be able to troubleshoot their ATM-based network like they do today on shared media LANs by only attaching a protocol analyzer. Furthermore, with the currently envisioned corporate enterprise networks where the management domain spans from the desktop to the wide area, high volumes of network management and control data coupled with connection-oriented environment make the problems extremely more complex. More and more, users are discovering that managing the switched ATM environment with a single Unix-based simple network management protocol (SNMP) system is becoming impossible. In addition, SNMP itself raises issues of security, scalability, and efficiency. (Federline, G. E., 1995, p. 70)

The new challenges ATM network management applications must address are multipoint connectivity, virtual connections, multiple classes of services, and high-speed cell network. If these areas are not addressed, the ATM network will run inefficiently and

ineffectively. Also, ATM's vast capabilities over current shared-medium networks will not be as great. A brief summary of the areas that should be addressed are provided in the following sub-subsections (Alexander, P., 1995, p. 48).

a. Multipoint Connectivity

ATM is a multipoint network architecture. Managing the network means managing multiple links from each switch, and multiple paths throughout the network. The task of managing multipoint connections in a WAN that uses an underlying TDM network has been largely performed be routers. This two-tiered management approach does not solve the problem of expensive, wasted bandwidth in the router portion of the network; it simply increases the complexity of the overall management task.

b. Virtual Connections

Each connection in a TDM network is a physical link carrying several channels defined through the process of time division multiplexing. ATM networks use virtual connections defined by virtual path and virtual channels identifiers carried in each cell. These virtual connections typically use several different physical links within the network, requiring much more sophisticated service provisioning than TDM and router-TDM networks.

c. Multiple Classes of Service

Each ATM class of service is defined be specified quality of services (QoS) parameters and guarantees. Every virtual connection has a specified guarantee of service, and each must be managed from end-to-end, based on the requisite QoS. At the same time, an individual connection's class of service must be managed in relation to other virtual connections in the network using different classes of service. Carriers and large enterprise network operators are no longer simply managing physical connections, but are now responsible for assuring the quality of many virtual connections.

d. *High-Speed Cell Network*

As discussed in the previous chapter, ATM services use small, fixed-length cells running over a high-speed transmission infrastructure. This poses three challenges:

- A problem in one part of the network can affect a large portion of the network or even the entire network before it can be reported to the central management station. In this situation, the network must be capable of addressing the problem before the information reaches the management station.
- The network management system must be capable of handling a large number of fault messages stemming from a single fault. Broadcasting all fault messages to all management stations in the network can itself cause congestion. A different fault reporting procedure is required.
- A large amount of data must be collected and reported to provide useful information about network trends and events for billing, analysis, and planning. SNMP is not capable of forwarding this data to central management for efficient storage and processing.

3. Projected Resolution of ATM Network Management

No date has been set as to when complete ATM standards and specifications for network management will be released. Also, network management, though it is important, is not a priority on the ATM Forum agenda. Because the ATM Forum has not shown a critical interest in network management, vendors are designing their own network management protocols to address the aforementioned potential network management problems, and to meet customers' needs. These actions will result in compatibility and interoperability problems as ATM WANs are connected. The WANs will consist of multi-vendor products, and if these products use various network management functions with non-standard protocols and interfaces, the users will not be able to effectively manage end-to-end connectivity across the network. Nor will the user be able to access the level of activity analysis necessary for effective network planning (Alexander, P., 1995, p. 49).

D. SIGNALING

1. Overview

Before any information exchanges between end points, some type of signaling is performed to setup connectivity to establish virtual circuits. This signaling is initiated by the requesting user for negotiation with the network with respect to available resources (VCI/VPI, throughput, and QoS). The signaling is also performed over a separate signaling virtual channel.

In order for the signaling to occur, the user and the network must understand the request and the response. To do this, standards are a must. A set of signaling standards have been established, and they are the foundation upon which switched ATM services will be built.

While the initial standards have some limitations, and can only cope with relatively simple calls, they form a starting point from which manufacturers and operators can begin to offer switched services on their ATM networks. (Jeffrey, M., 1994, p. 1)

2. Problem

The ATM Forum published the first signaling standard, the User Network Interface (UNI) version 3.0. This standard included a basic signaling protocol for LAN environments with local ATM switches and terminals. The ITU's UNI protocol has been completed in ITU-T Recommendation Q.2391 (previously known as Q.93B), and is closely aligned with UNI v3, but is designed for communicating with public networks.

UNI v3 and Q.2391 are similar in that they only support the "Release 1" service. This is limited to simple ATM calls with a single connection to a single party (Type 1 connection). Also, the bandwidth for the call is specified by the caller and cannot be negotiated with the called party, nor can the bandwidth be changed during the life of the call. This basic service is sufficient for many purposes, including LAN interconnect and the transport of most POTS and ISDN services. However, the service is lacking when it comes to using the network for multimedia applications such as video-on-demand. (Jeffrey, M., 1994, p. 1)

3. Projected Release of Complete Signaling Standards

Following the release of "Release 1," the ITU begin defining the requirements for the subsequent stages. For manageability reasons, the stages have been segregated into Capability Sets. The next stage is the design and formulation of protocols for Capability Set 2 (CS2). CS2 protocols will be capable of the following:

- Negotiation and Modification - The calling party will be able to offer the called party a choice of bandwidth options rather than the "take it or leave it" provided by Release 1.
- Point-to-Multipoint (Type 2) Connections - The ATM Forum's UNI v3 protocol supports limited point-to-multipoint connection. As a result, the ITU's will more than likely adopt this approach to be compatible.
- Multi-Connection Calls - CS2 will include the support for many point-to-point connections in the same call. This will allow the transport of service components (within a multimedia call) over bearers with appropriate bandwidth and QoS.
- Multiple Multipoint Connections - This signaling protocol will provide ATM switches the ability to support a mixture of point-to-point, and point-to-multipoint connections in the same call. Some of the connections will not originate from the same source as others.
- Multipoint-to-Point Connections - This will allow "fan-in" connectivity.
- All-points to All-points - to provide a "bus" like interface where all ATM cells are copied to all parties on the connection.

The final stage on the signaling protocols is Capability Set 3 (CS3). These protocols will oriented toward new intelligence and services. Some of the services include the following:

- Internetworking with the Intelligent Network - This will allow the implementation of Freephone and Selective Redirection for ATM terminals.

- Embedded Multimedia Functions.
- True Broadcast Service - This feature allows the support of Cable-TV style broadcast services over ATM networks.
- Evolution towards Telecommunications Information Network Architecture (TINA) - This protocol allows the construction of future network control architecture from distributed computing principles.

The CS2 capabilities should be available in 1995. Studies have begun on the requirements for CS3. The signaling protocols should support CS3 functions in 1996 or 1997.

E. CONGESTION AND FLOW CONTROL

1. Problem

Congestion control techniques are of utmost importance in an ATM network. Without these techniques, user traffic on the network could exceed the capacity of the ATM switches. This traffic overload would cause the ATM switch memory buffers to overflow, resulting in cell loss. The cell loss may require the retransmission of thousands of cells.

Congestion-induced cell loss is more difficult to prevent in an ATM network than in networks using "today's" technology (shared medium), such as an Ethernet network. An Ethernet network uses the MAC to help prevent loss because hosts sense the network before transmitting data to prevent or minimize collisions. In contrast, on an ATM network each host is connected to the switch using dedicated links. These links cannot sense if cross traffic will be encountered at intermediate switches. Since switch buffering is limited, and the transmission rate is fixed, buffer overflow can easily happen. (Brustoloni, Jose' Carlos, 1994, p. 324)

The complexity of the cell loss problem is compounded by the limited number of overhead bits available to exert control over the flow of user cells. This area is currently the subject of intense research, and no consensus has emerged for a full-blown traffic and

congestion control strategy. Accordingly, ITU-T has defined a restricted initial set of traffic and congestion control capabilities aiming at simple mechanisms and realistic network efficiency; these are specified in I.371. The ATM Forum has published a somewhat more advanced version of this set in the ATM UNI Specification 3.0. [Stalling, W., "ATM Congestion Control: A Practical Issue for Users and Providers," 1995, p. 34]

2. Release of Congestion and Flow Control Standard

The ATM Forum's congestion control standard was decided between two solutions, a credit-based scheme and a rate-based scheme. The credit-based solution requires window flow control on a per-link, per-VC (virtual connection) basis. Each link has a sender node and a receiver node that maintain a separate queue for each VC. The receiver determines the number of cells the sender can transmit by monitoring the queues on each VC, then issues a "credit" that determines how much data the sender can transmit.

The rate-based scheme provided end-to-end control using single-bit feedback. The switch monitors the network by using the feedback bits. When congestion is detected, the switch adjusts the data rate until the heavy traffic goes away.

The Forum selected the credit-based scheme because it allows zero cell loss, while the rate-based scheme requires that the switch be capable of sufficient buffering to prevent cell loss. (Chernicoff, David P., 1995, p. N3)

F. IP OVER ATM

1. Overview

IP runs over various transmission media, including Ethernet, Token-Ring, Fiber Distributed Data Interface (FDDI), X.25, Frame Relay, Switched Multimegabit Data Service (SMDS), and many others. Now procedures must be formalized to run IP over ATM.

IP is the "glue" which allows the variety of protocols to communicate across networks or the Internet. Each protocol can be viewed as running in its own subnet. The subnets are connected by routers to form the internet. As shown in Figure 3.2, the sending host computer formats (encapsulates) an IP packet to send to the receiving host.

This IP packet is encapsulated within the subnet protocol of subnet A and delivered to the router between subnets A and B. The router strips off subnet A's protocol information, and retrieves the IP packet. The packet is then encapsulated in subnet B's protocol. This process continues until the original IP packet reaches the receiving host.

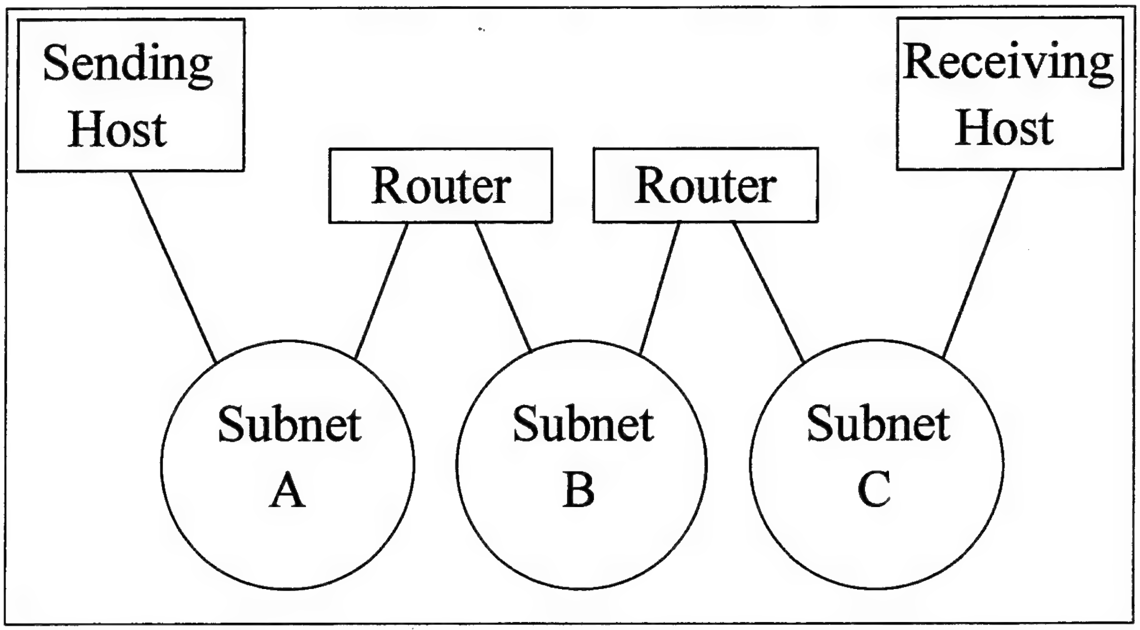

Figure 3.2 An Internet with Four Subnets

2. Problem

The primary problem or difference between IP and ATM is that IP is connectionless oriented and ATM is connection oriented. On an IP network, no connection is set up before any information is sent from the sending node to the receiving node. Also, the information or packets may traverse different paths before reaching the destination. At the destination, the packets are resequenced and reassembled to obtain the original message.

On an ATM network, a connection or virtual path is established between the end points before the sending host transmit information down the path. The information or cells arrive at the destination in the same order that they were transmitted. Therefore, no resequencing is necessary.

Another difference between IP and ATM is the use of addresses. IP uses addresses as a means of sending packets to the appropriate destination. ATM does not use addresses. Instead, it uses virtual paths and virtual channels.

3. Projected Release of IP over ATM Standard

A number of protocols other then IP have already been standardized to operate over ATM (SMDS and frame relay). Technically, IP can run over one of these protocols over ATM. For example, if an organization already has frame relay routers in place using lease lines, the lease lines could be replaced by ATM service using ATM data service units (DSUs), which provide a router-compatible interface. (Witt, Michael, 1995, p. 54)

Another alternative of running IP over ATM is to change or not use IP. This step would allow direct mapping between TCP and connection-oriented services. Though the method may have some advantages, it is a big step away from the TCP/IP architecture. As a result, this alternative will more than likely not be chosen.

The Internet Engineering Task Force (IETF) IP over ATM working group is currently writing proposed standards for IP over ATM. The working group fielded two draft standards or request for comments (RFC) that address running IP over ATM.

RFC 1483, "Multiprotocol Encapsulation over ATM Adaption Layer 5," discusses a number of different protocols that may be either routed or bridged over ATM networks. This draft covers protocol multiplexing and encapsulation issues. It defines two possible methods of multiplexing, and specifies the encapsulation format to be used with each method (Witt, Michael, 1995, p. 54).

RFC 1577, "Classical IP and ARP over ATM," addresses IP over ATM specifically. It uses the term "classical model" to describe ATM integrated with IP as a standard subnet protocol. This protocol would match the IP addresses to their corresponding ATM addresses (Alles, A., 1995, p. 36).

No projected date has been set as to when the IP over ATM standard will be completed. Because the IETF is independent of the ATM Forum and anyone can be a member of the ITEF, it may be sometime before the standard is released.

G. APPLICATION PROGRAMMING INTERFACE (API)

1. Problem

Vendors and users have two varying views of the use of ATM technology. The manufacturers feel that the technology should be used to increase bandwidth in corporate LANs and WANs, while users envision ATM being extended to the desktop.

Though these views have "opposite" poles, both parties agree that in order to increase the demand of ATM to the desktop, a new class of applications must be developed to exploit the ATM technology. These new applications would use services provided by ATM networks, such as switched virtual circuits, specification of bandwidth, and QoS guarantees. These services are not available in today's Ethernet or Token-Ring environments. If new ATM applications are not developed, users will have little or no incentive to install ATM NICs in their desktops. Instead, they may upgrade their network to Switched Ethernet technology, connecting to ATM backbones to meet their bandwidth needs. (Harford, J., p. 19)

Though there is a lack of API standards, many leading-edge ATM vendors are shipping or planning APIs that allow access to the ATM protocol stack. However, the APIs are all different. As a result, application writers must tailor an application to a specific ATM vendor's NIC. This may cause application writers to avoid ATM, thus relegating the technology to the backbone. Also, the use of vendor-specific APIs create interoperability problems, and forces the user to one vendor or a group of allianced vendors.

2. Projected Release of API Standards

Recognizing the need for an ATM API, the ATM Forum chartered a working group to address this challenge. The group is currently defining a semantic (not syntax) specification of such an API. The semantic specification will provide details of the interface between an application and the underlying ATM protocol stack, but will leave room for different syntaxes to account for the operating environment and language bindings. For example, an application written in C for a UNIX environment might require

porting to an object-oriented workplace OS, but the porting would be simplified because the underlying ATM protocol implements the same services in both environments. (Harford, J., p. 19)

The specifications the API working group is developing will not only be designed for portability, but also for multivendor interoperability.

It is projected that the ATM API specifications will be completed in late 1995. However, vendor implementation is not expected until spring or summer or 1996.

H. FIREWALLS

1. Overview

An unresolved issue related to public ATM networks is the use of firewalls. A firewall is a combination of software and hardware used to keep unauthorized individuals from accessing a private LAN. (Buerger, D. J., p. 79) The firewalls normally run on a dedicated workstation external to the LAN, but inside the router link to the internet. As an illustration, a firewall may allow FTP access from a public network to a private network. This same firewall may prohibit Telnet access.

Firewall components normally consist of one or more of the three techniques: packet filtering, application gateways, and circuit gateways. A brief description of each technique is provided below (Buerger, D. J., p. 79).

- Packet filtering is usually performed by a router as data packets pass through the router's interfaces. The filter reads fields in Internet Protocol (IP) packets such as source and destination IP addresses and TCP/User Datagram Protocol source and destination ports. By checking these fields, the packet filter can allow passage of trusted packets, or disallow passage of packets from unauthorized sources.

- Application gateways are proxy servers that funnel approved users to the appropriate application server. For example, inbound Internet users who want to use a corporate E-mail, FTP, or WWW server could access those services only after authentication by proxy servers located outside the corporate LAN.

- A circuit-level gateway relays TCP connections between specific sources and destinations. These gateways do no filtering; they simply pass bytes back and forth. An example is a Telnet gateway, which would service the Telnet session once the gateway permits its establishment.

2. Problem

Many networking experts are not sure whether firewalls can be used in an ATM environment. The main problem is that once an ATM connection is established, no intermediate devices generally interpret or process any of the information traversing the connection. Once a connection is established between two end nodes, any data could be sent down the connection without visibility to network administration. While firewalls, or other security devices, could be implemented in the end systems, it is not likely to be a practical solution for most end units. (Alles, A., 1995, p. 23)

Many proposals have been written recommending that firewalls be used at connection set-up time instead of on the transmitted data. Special information elements would be defined within the signaling message to indicate the type of access (specific application, Telnet, FTP, etc.) is required. The intermediate switches would then filter the connection set-up based on the information element, source and destination addresses, etc.

Another approach to tackling the firewall issue is the use of ATM address filtering. Address filtering could be used at private, public, and shared WAN network points to only allow connectivity between trusted addresses, and prevent general connections.

3. Projected Resolution of Firewall Issues

Though the two aforementioned recommendations may have some utility, they are limited by the fact that little prevents an end system from lying about the use to which a connection would be used, since ATM connections generally terminate at lower levels within end system protocol stacks, and not at the actual applications. As a result, once a connection is set up, a node could send packets of any protocol type down the connection, and have these demultiplexed at the destination to any supported application, regardless of

the identity of the application to which the connection was set up to. (Alles, A., 1995, p. 23)

Cryptographic based authentication mechanisms is a feasible solution to tackle this problem. These mechanisms can be added to the ATM signaling.

The ATM Forum has begun preliminary work on using security mechanisms. However, it will be some time before complete specification are released. In the meantime, network administrators continue to use routers as security walls. Some routers are even used to connect two ATM switches to each other. Though this type of set up affects performance and service, many network administrators prefer this type of solution to not having any firewall protection.

I. CHAPTER SUMMARY

Though ATM has tremendous capabilities and bandwidth power, many implementation issues must be addressed, and standards must be released addressing these issues. This chapter discussed several of the implementation issues, such as LAN Emulation, network management, signaling, congestion and flow control, IP over ATM, APIs, and firewalls. Failure to address these issues leads to compatibility and interoperability problems. To circumvent these problems, one would have to buy proprietary products and lock himself or herself into one vendor. This would place the organization at a tremendous disadvantage should the vendor discontinue manufacturing ATM products.

Another key point to remember is that if the future specifications addressing the implementation issues are not clear and precise, vendors will implement the specifications using various interpretations. This too could lead to interoperability problems. To avoid this problem, the specifications must be clear.

Several issues were addressed in the previous sections. However, there are many more issues which the ITU, ATM Forum, and applicable standards making bodies must address. One in particular is the frame relay, and cell relay compatibility problem. Though the Frame Relay Forum and the ATM Forum agreed on how frame relay and ATM interoperates, the agreement is rudimentary and needs additional work. The

specification falls short of full interoperability because it does not address transfer between a generic ATM interface, and a generic frame relay interface. Without this kind of base-level interoperability, the device on the ATM network must know that it is communicating with a frame relay device, and it must treat that device differently than it would another ATM device. It must run frame relay software, which means running two protocol stacks at the upper layer. This makes administration difficult, and can be costly in terms of processing power and resources. (Taylor, S.,1993, p. 23)

Another implementation issue is voice over ATM. Though ATM has been "preached" about its ability to send data, video, and voice, the ATM primary focus has been data and video. The ATM Forum recently started a new work effort to study how voice can be carried efficiently by ATM, and a new ATM adaption layer (voice AAL) is being discussed. (Harford, Jim, "ATM must Make Way for Voice," p. 33)

The final implementation issue that will be mentioned is cell efficiency (control characters, and information characters). Approximately 10% (5 bytes) of the 53 bytes of an ATM cell are dedicated to the header of the cell, and the remaining 90% (48 bytes) carry information. When comparing this information to Ethernet packets, usage of the ATM cell format is very inefficient. An Ethernet packet size ranges from 26 bytes to 1,526 bytes. There are 26 control bytes in an Ethernet packet. This equates to approximately 0.017% of the total 1,526 bytes in a full packet being used as control characters.

IV. ASSESSMENT OF SYSTEMS MANAGEMENT'S LAB LAN

A. INTRODUCTION

1. Purpose of Chapter

The purpose of this chapter is to provide a general overview of the SM Department computer lab LAN. This chapter is not intended to discuss the intricate details of the network topologies of the LAN and how the various topologies function. Instead, the chapter will provide a macro-picture of how the computer labs are physically and logically connected, the types of topologies used, and the hardware and software used on the network.

The SM Department computer lab network has been in transition for the past year. While this thesis was being written, PC LAN was installed on the network. Since then, the computer lab network has been upgraded to Windows for Workgroup (WFW). This upgrade is not included in the baseline assessment.

2. General Overview

The SM Department of the Naval Postgraduate School has three microcomputer labs which are located in Ingersoll Hall, rooms IN-158, IN-224, IN-250. The labs in IN-224 and IN-250 are used as instructional labs; IN-158 is used for research. Only Naval Postgraduate School students, faculty, and staff are authorized to use the labs.

A Token-Ring network interconnect the three labs, providing connectivity to two instructor computers, 41 user computers, ten servers, and an assortment of ancillary components.

In addition to the Token-Ring network, the SM Department also operates a 3Com 10 Mbps Ethernet LAN, a 230.4 Kbps AppleTalk LAN, and a PCLAN. The following sections provide detail information on these various networks.

B. TOKEN-RING LAN

The Token-Ring network conforms to the IEEE 802.5 standard and operates at 16 Mbps. The network establishes a ring topology using multi-station access units (MAUs) and shielded-twisted pair cabling. A depiction of the ring is provided in Figure 4-1. To better manage to network, the network has been segmented into three sections (0TR, 4TR, and 8TR). These alpha-numerical designations correspond to rooms IN-250, IN-224, and IN-158, respectively.

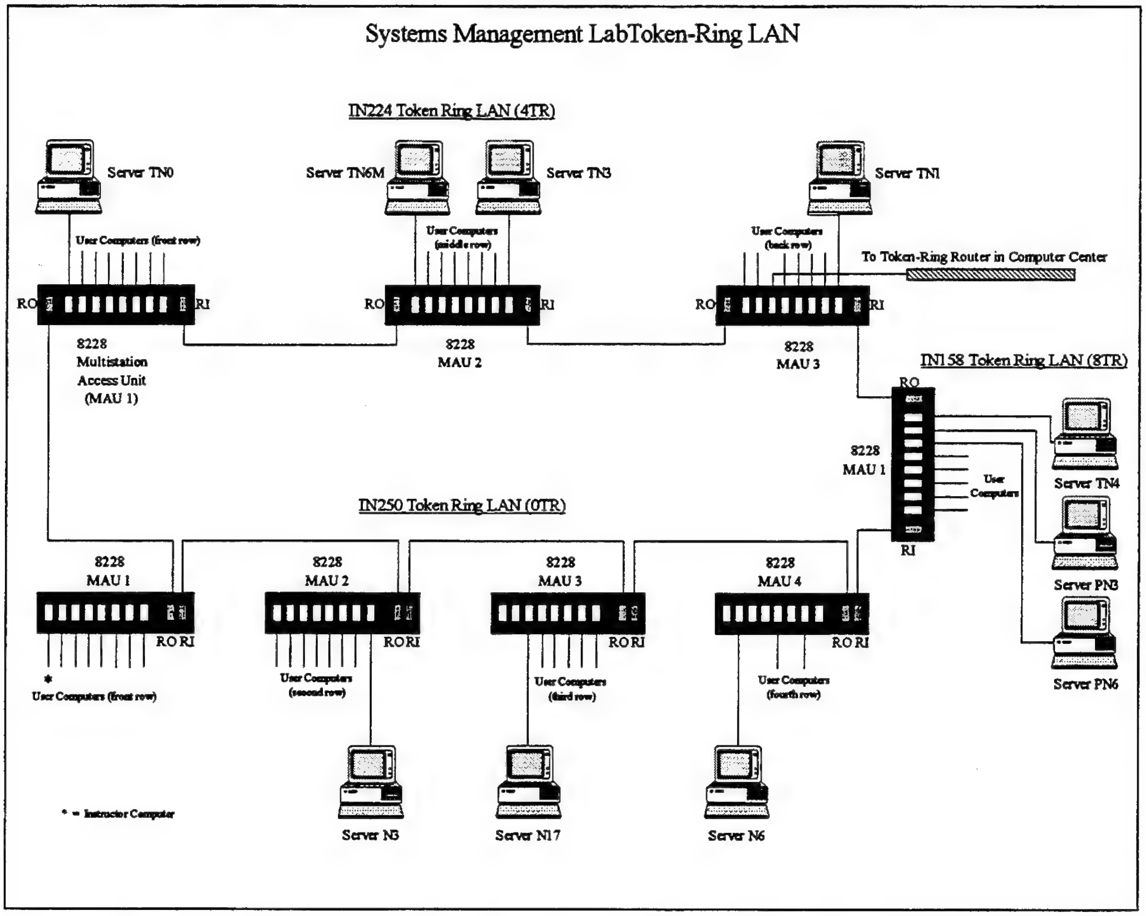

Figure 4.1 Systems Management Lab Token-Ring LAN

1. Topology

The Token-Ring network uses a logical ring topology. Tokens and messages pass, uni-directionally, from station to station, with each station acting as a repeater. This type of network uses a token-passing scheme for network access. In order for a node to

transmit data, it first must gain control of the token. The token is a specific bit sequence that circulate amongst the nodes. Once a node possesses the token, it can transmit a message that is in its output buffer.

To allow messages to be routed to a particular node or a group of workstations, an Internet Protocol address is assigned to each station. Communication is established and maintained using PC LAN version 1.21 software.

Though Token-Ring is based on a logical ring topology, the computers are actually connected to MAUs using a physical star topology. A MAU serves as a multi-port hub connecting up to eight computers. The MAU routes messages between the stations to maintain the logical ring, while providing individual physical connectivity to each station.

MAUs also contain two ports to connect to other MAUs. These ports are designated as Ring In (RI) and Ring Out (RO). Figure 4.1 illustrates how 0TR, 4TR, and 8TR are interconnected using the RI and RO ports of the eight MAUs which makeup the SM Lab Token-Ring LAN.

To reduce crosstalk and noise, shielded twisted pair (STP) cabling is used to connect the MAUs and the computers. Network Interface Cards (NICs) or network adapters are installed in each computer to allow connectivity to the computers.

2. Configuration

a. Instructor and User Computers

The instructor and user computers are 486/33 DX computers. Each machine is equipped with a regular suite of input/output devices such as keyboard, monitor, mouse, and dual floppy drives (3.5 and 5.25 inch). Several computers are equipped with additional peripherals such as modems, CD-ROMs, projectors, and scanners. Some computers also have 3270 emulation capability.

Each computer has a CONFIG.SYS and an AUTOEXEC.BAT file in its root directory. The CONFIG.SYS file customizes DOS while it is being loaded into memory during the boot process and loads the various device drivers to establish a logical

between the device and the entire system. After DOS has been loaded into memory, the AUTOEXEC.BAT file is run. This file sets paths to the logical or physical disk drives and directories, loads specific operating files (when needed), and establishes environmental variables, as required. The AUTOEXEC.BAT file also sets parameters to display the current directory at the DOS prompt, and displays a standard screen. The screen display could either be a DOS prompt to load Windows or instructions to log into the network.

The CONFIG.SYS and AUTOEXEC.BAT files are executed each time the computer is "booted." Their executions are automatic and transparent to the user.

Besides the CONFIG.SYS and AUTOEXEC.BAT files, other batch files are used to allow the user quick and easy access to various applications on the network. These applications may be located on different servers. When the user exits the application, the batch file executes additional DOS commands to return the computer to the standard network configuration.

b. Servers

The Token-Ring network currently operates ten servers: eight 486 DX 33 MHz computers and two pentium computers. The location of the servers is shown in Figure 4.1, page 51.

IN-224 contains four of the servers. Two servers function as files servers, one doubling as a print server. The other two servers provide gateway access to the mainframe computer in the Church Computer Center (Ingersoll Hall). Nine of the user computers in IN-224 are configured with 3270 emulation software to access the mainframe computer via the Gateway servers. As a last note, all of the user computers in IN-224 operate as DOS-based machines and runs only DOS applications.

The user computers in IN-250, the 0TR segment of the Token-Ring network, can run either DOS- or Windows-based applications. These computers access the Pentium servers in IN-158 to run applications. One of the three 486 DX 33 MHz servers provide print services to the users in IN-250. The remaining two servers provide no services.

Finally, the 486 server in IN-158, the 8TR segment of the Token-Ring network, provides file and print services to five user computers. Like the user computers in IN-250, these computer run DOS- and Windows-based applications.

c. *Protocols*

The Token-Ring network not only uses the IEEE 802.5 protocol. It also uses Transmission Control Protocol/Internet Protocol (TCP/IP), Terminal Emulation (Telnet) protocol, File Transport Protocol (FTP), and SIMPC. These protocols provides the following functions.

- TCP/IP is a set of communications protocols that encompasses media access, packet transport, session communications, file transfer, electronic mail, and terminal emulation. All network traffic use these protocols while traversing the network. Also, this protocol is used to communicate with the mainframe computer in the Church Computer Center.
- TELNET is a terminal emulation protocol that provides remote terminal-connection services. This protocol can be used to connect to either the computer center's mainframe or a workstation.
- FTP is used in conjunction with TCP/IP to log in to a network or host, list files and directories, and transfer files. This can either be done between PCs, or a PC and a mainframe.
- SIMPC is a terminal emulation program used in conjunction with a modem. This software allows a PC to connect to a mainframe or a workstation and transfer files between a PC and a mainframe.

3. Token-Ring Segment 4TR (IN-224)

This segment interconnects four servers (two gateway servers, and two file servers), an instructional computer, and 15 user computers. Three IBM 8228 MAUs provide the interconnectivity. STP cabling is used to connect the servers and computers

to the MAUs. A STP cable run functions as a link to the campus backbone. Figure 4.2, on the next page, depicts the connectivity.

Peripheral equipment such as a graphics scanner, an external CD-ROM reader, a Hewlett-Packard DeskJet 500 printer, and a video projection system are also located in IN-224. The scanner and CD-ROM reader are attached to user computers, and the projector is connected to the instructor computer. The printer is connected to the server designated as TN6M.

The 2400 baud internal modems are installed in the instructor computer (TN18) and five user computers (TN20, TN21, TN22, TN24, and TN25). These modem are used to access the Computer Center's mainframe and Sun Workstations, or remote access to other networks.

Nine computers (the instructor computer and eight user computers) have 3270 emulation capability. These computers use the IBM 3270 User-version Emulation Software to connect to the Computer Center mainframe via the two 3270 Gateway Servers (TN0 and TN1). These servers access the mainframe through an IBM 3174-1L Controller. Coaxial cable is used.

4. Token-Ring Segment 0TR (IN-250)

This segment interconnects three 486 servers, an instructor computer, and 21 user computers. This segments comprises four MAUs which functions as the central hubs for up to eight computers. The MAUs are connected using the RI and RO ports. Figure 4.3, on page 58, provides a diagram of how the computers are connected to 0TR.

Server N3 functions as a dedicated Systems Architect (a software design tool) server. No other services reside on this server. Server N6 provides no services, and Server N17 provides print services.

The computers on this segment use WFW, and access DOS- and Windows-based applications from the Pentium servers in IN-158.

The instructor computer (N9) and six user computers (N10 through N15) are configured with 9600 baud internal modems. These modems allow access to the

Computer Center mainframe and the Sun Workstations. The modems also permit access to the Token-Ring network from remote locations.

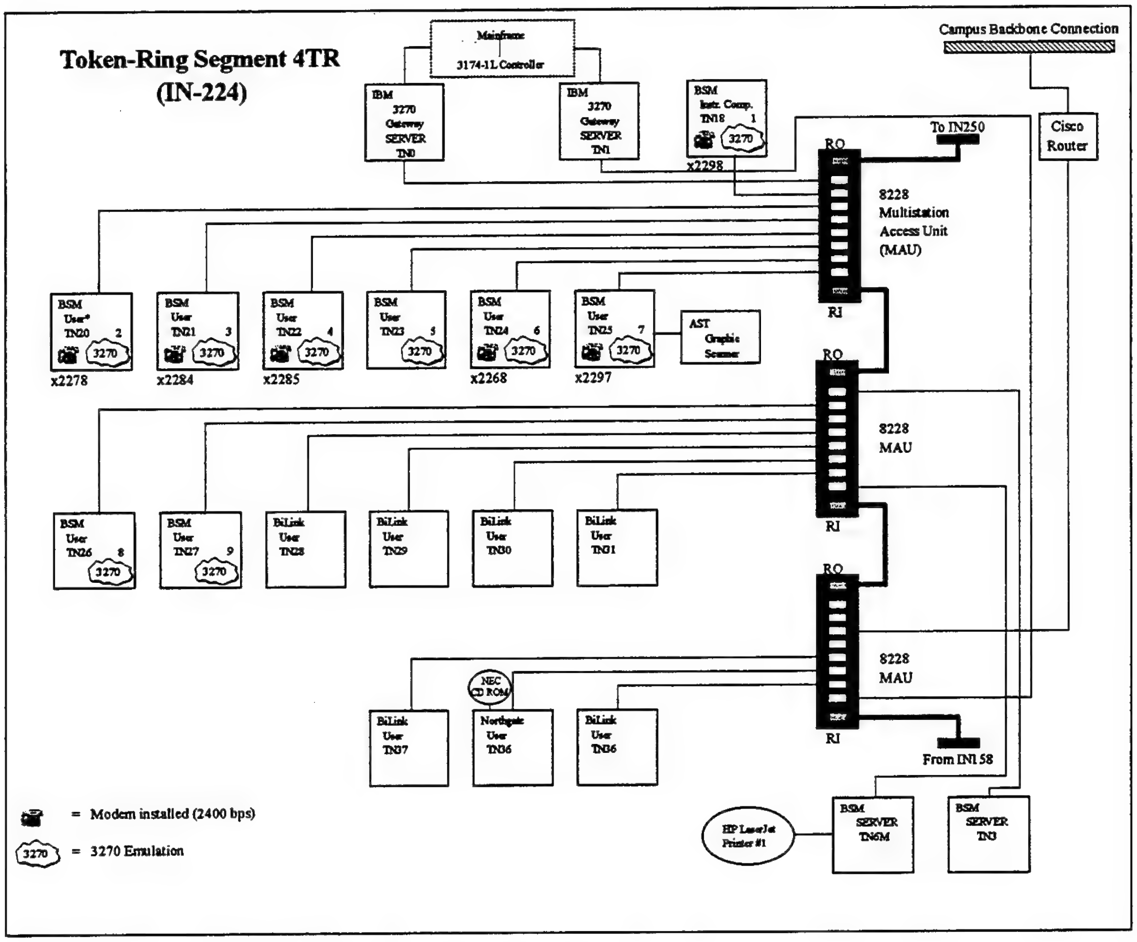

Figure 4.2 Token-Ring Segment 4TR (IN-224)

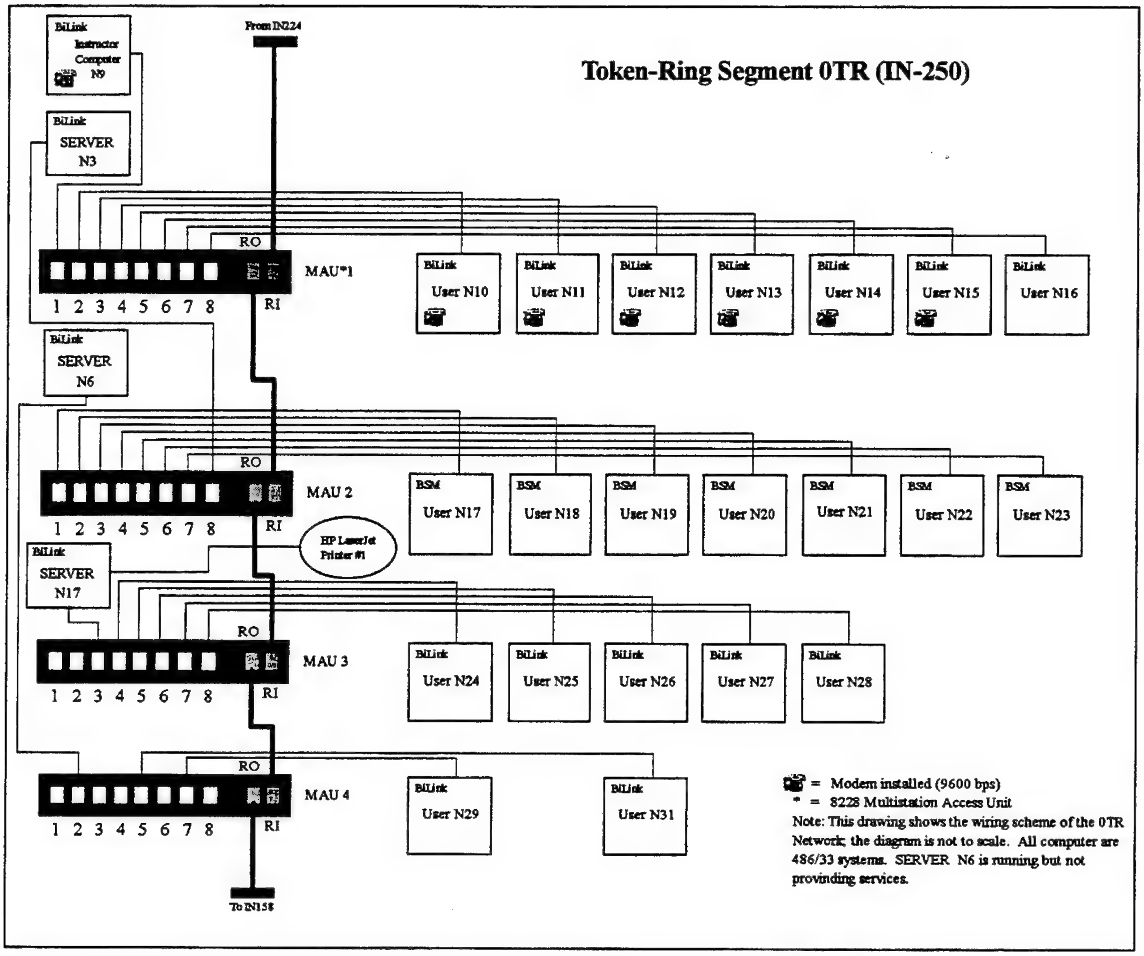

Figure 4.3 Token-Ring Segment 0TR (IN-250)

5. Token-Ring Segment 8TR (IN-158)

IN-158 is the Software Metrics Lab. The segment in this lab comprises two Pentium servers, one 486 DX 33 MHz server, and five user computers. One MAU is currently used in this segment for interconnectivity. A third Pentium server will be connected to this segment in the near future. Figure 4.4, below, shows the current segment configuration.

The Pentium servers (PN3 and PN6) provide DOS- and Windows-based application services to users in IN-250. These servers also run WFW. The 486 server (TN4) provides DOS- and Windows-based application services and print services to user computers in IN-158. The third Pentium server will be configured as a Windows NT server when it is added to 8TR.

3270 emulation cards are installed in each user computer for coaxial connectivity to the mainframe via an IBM controller.

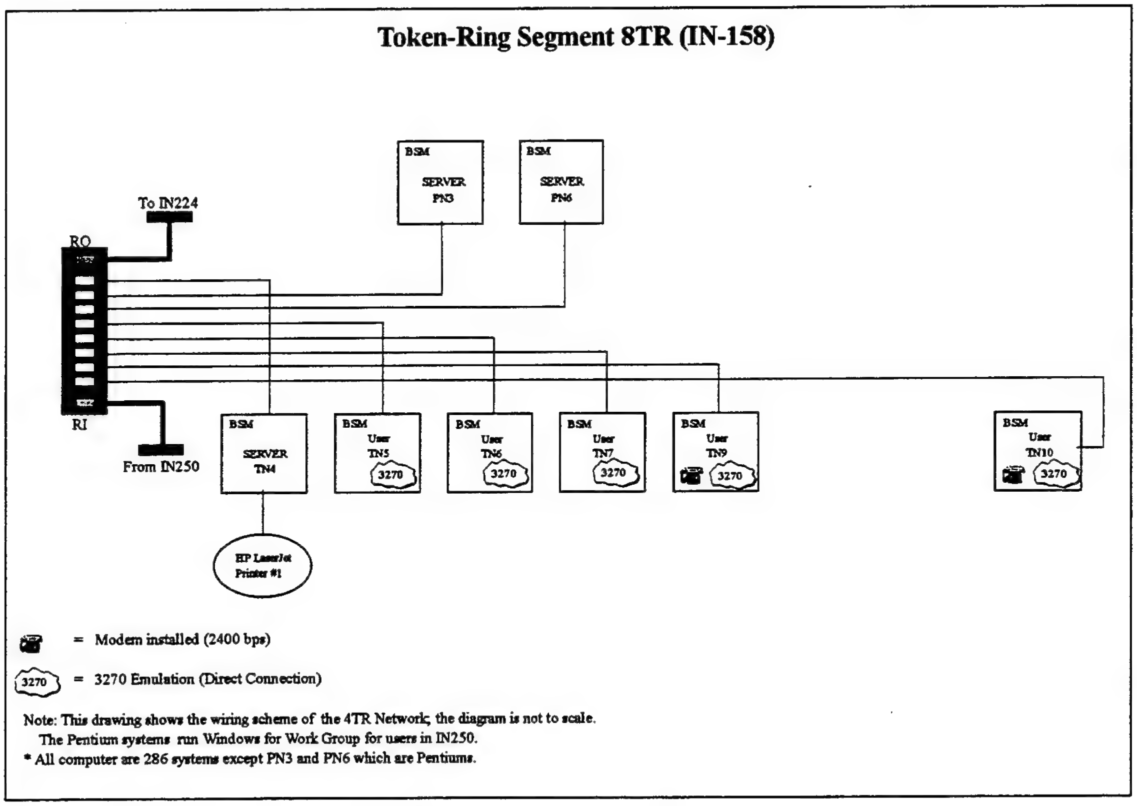

Figure 4.4 Token-Ring Segment 8TR (IN-158)

C. ETHERNET LAN

The Ethernet LAN runs at 10 Mbps and consists of a 3Com Server and four 486 DX 33 MHz user computers. The server provides file and print services. A Hewlett Packard DeskJet 500 is attached to the 3Com Server. The server and user computers are individually connected in a star arrangement, using Thinnet coaxial cable, to an eight-port Ethernet Repeater. A separate port, the Attachment Unit Interface (AUI) Port, is used for connectivity to the Campus Backbone. The repeater is a centralize connection provides reliability and ease of connection and disconnection.

Each user computer runs TCP/IP software. Although ENET4 is physically connected to the Ethernet Repeater, it is not part of the network. It does not run the

3Com software. It is configured for access only to the campus backbone using the TCP/IP software.

Figure 4.5, on the following page, depicts the Ethernet LAN.

D. APPLETALK LAN

The AppleTalk network consists of six Macintosh Plus computers. One Macintosh Plus functions as the server. A Laser Writer is also connected to the AppleTalk network to provide printing capabilities. The Apple network uses its own Apple protocol. Another unique feature of this network is the use of proprietary AppleTalk cables and connectors. The network runs AppleShare software for file sharing and communications between the users. AppleTalk is used for print services. The AppleTalk LAN is dedicated to research, and will possibly be upgraded to Ethernet Standards. Figure 4.6, on the next page, provides a layout of the network.

AppleTalk is a proprietary network standard and does not conform to IEEE standards. The network is baseband and functions in a bus topology. AppleTalk can function over STP, UTP, and fiber optic cable. It runs at a speed of 230.4 kilobits per second, and uses an access scheme similar to the Ethernet Carrier Sense Multiple Access/Collision Detection, or Carrier Sense Multiple Access/Collision Avoidance.

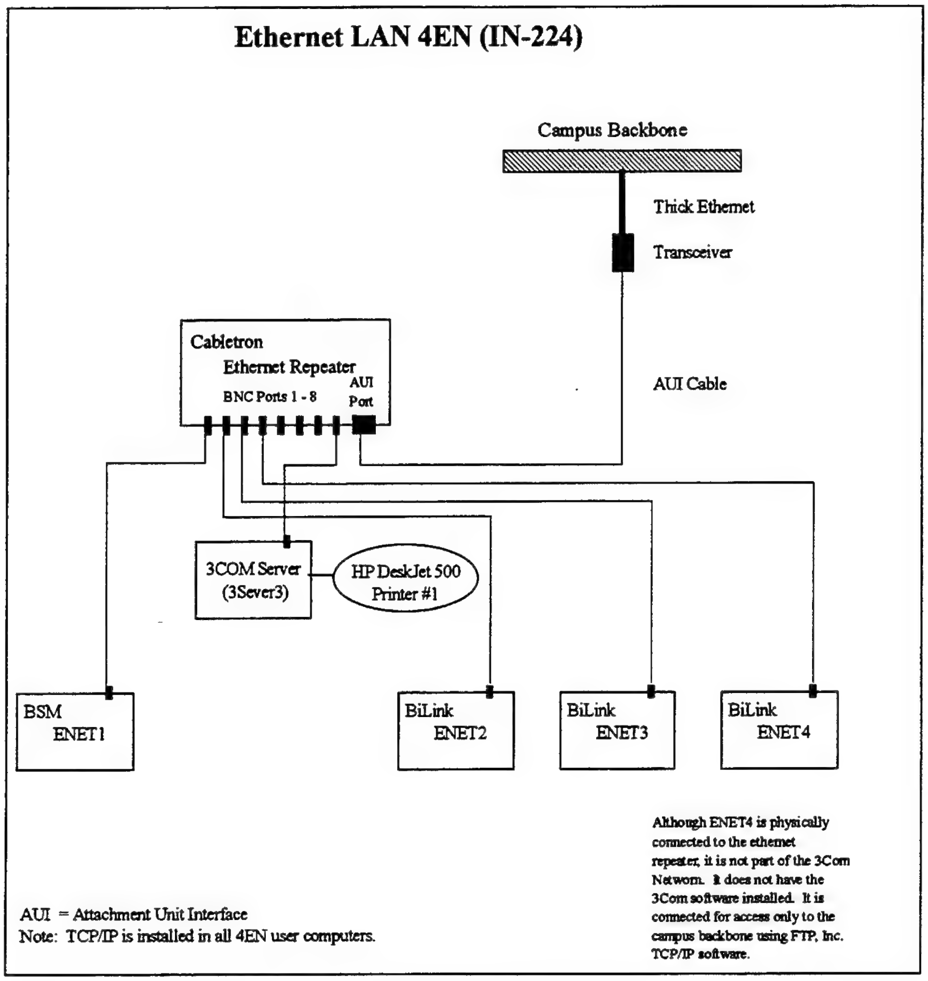

Figure 4.5 Ethernet LAN 4EN (IN-224)

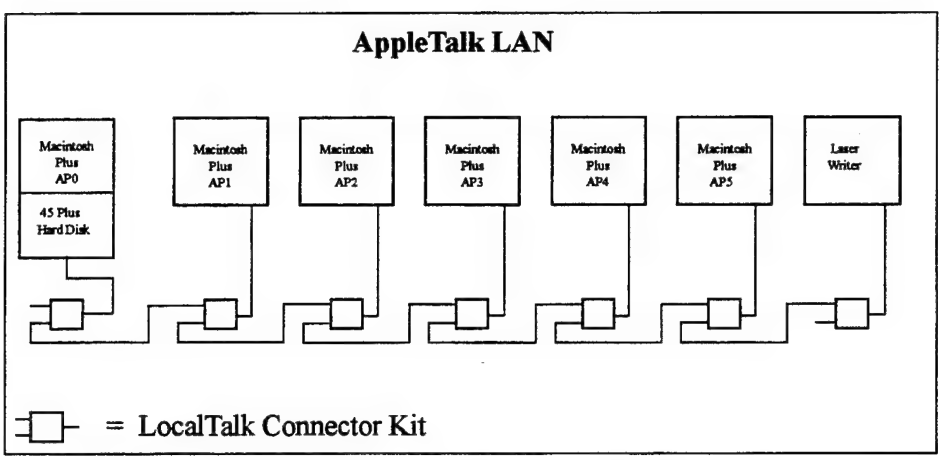

Figure 4.6 AppleTalk LAN

E. PCLAN NETWORK

The PCLAN network comprises a server and two user computers. These components are connected through a translator (hardware). This network is a standalone network and functions as a test bed for implementing new network hardware and software. The server runs many DOS-based applications.

F. CHAPTER SUMMARY

This chapter provided an overview of the SM Department computer lab network. The labs use various network protocols to support the facets of LANs that to provide file and print services to NPS faculty, staff, and students. The servers provide either DOS- or Windows-based applications services, or both. The Token-Ring LAN has two Gateway Servers for access to the mainframe computer, and a dedicated run to the campus backbone. The Ethernet network also has a dedicated run for access to the campus backbone. Two LANs (AppleTalk and PCLAN) functions as stand alone LANs.

V. APPLICATION OF ATM TECHNOLOGY TO LANS

A. PURPOSE OF CHAPTER

The purpose of this chapter is to provide an illustration of an implemented ATM network and to design an ATM network that could replace the current lab network in the SM Department. I will discuss the Supercomputing 1995 Conference ATM network that was installed in the San Diego Convention Center. I assisted the coordinators of this ATM network while on thesis travel.

Though Supercomputing 1995 ATM network supported powerful workstations and mainframe computers on site and across the United States, the first-hand knowledge and actual configuration of ATM switches is applicable to the design of an ATM network for the SM computer labs.

B. SUPERCOMPUTING 1995 NETWORK

1. Overview of the Supercomputing Conferences

Supercomputing conferences provides computational scientists and engineers a worldwide forum to showcase their research. The scientists and engineers transport portions of their labs to the conference site, or connect their labs over high-speed networks to communicate, educate, and learn from one another. Presentations at Supercomputing promote the development of teams of computational scientists and computer scientists for large-scale problem solving. The presentations also foster technology transfer between scientists, industry, and future researchers. A third advantage of the conferences is the encouragement of collaboration among academia, government research labs, and industry.

Two key demonstrations of existing technology and future technology shown at Supercomputing 1995 was the GII Testbed, and the High Performance Computing (HPC) Challenge. A summary of these demonstrations are provided below. (Korab, H. and Brown, M. D., 1995, p. 2)

a. *GII Testbed*

The GII Testbed was an interactive 2D and 3D scientific visualization, and virtual reality demonstrations of research projects that used high-performance computing and communications to attack large scale problems. The applications were computed in the scientists' numerical labs, and then transmitted over the I-WAY (Information Wide Area Year, national scale, applications-focused, community-based ATM network) to the Supercomputing 1995 convention floor. The applications emphasized distributed, real-time heterogeneous computing, large data sets, remote instrumentation, collaboration, and advanced display devices.

b. *HPC Challenge*

The HPC Challenge was a forum for scientists who are on the leading edge to challenge the computational limit of heterogeneous computing in the race to the teraflop. The goal of the HPC Challenge was to assemble the greatest amount of computing power and speed to run a single scientific application on-site and over the I-WAY.

Most of the GII Testbed and the HPC Challenge applications were highly graphical. These applications were displayed in the following advanced virtual reality environments.

- Cave Automatic Virtual Environment (CAVE) - a 10 x 10 x 9-foot room-sized, multi-person, high resolution 3D video and audio environment.

- ImmersaDesk - a scaled-down version of the CAVE, about the size of a drafting table, that brings 3D virtual environment technology into the office. The ImmersaDesk is portable yet large enough to fill a persons field of view when he or she is seated in front of it.

- NII/Wall - is a large projection display created from four 1280 x 1024 screens. Like the ImmersaDesk, images appear on one plane and can be in stereo.

2. Implementation of the Conference Network

The network implementors and administrators used a variety of networking technology to provide connectivity to the participants, both on site and off site, of the Supercomputing conference. The technology ranged from ATM to FDDI, Ethernet, and Switched Ethernet.

The participants had access to their research data via the I-WAY and the internet. The I-WAY, an ATM testbed, was an experimental, high-performance and high-speed network which linked dozens of the United States' fastest computer and advanced visualization machines. The I-WAY also provided the backbone for all the high-end networking activities during the conference.

In order for the I-WAY to be accessible in major conference rooms, selected research and exhibit booths, video display kiosk, and other areas of the convention, the I-WAY was connected to the WAVE, the Wide Area Visualization Experimental. The WAVE LAN also supported visualization and virtual reality applications and video server technology within the convention center. Each application in the GII Testbed and the HPC Challenge accessed the WAVE through both ATM and Ethernet connectivity.

A second network which functioned on-site was the SCInet. This network was the production network which provided a seamless infrastructure throughout the convention center. The SCInet also provided external connectivity to the I-WAY and the internet, as well as internal connectivity among the booths, meeting rooms, electronic mail-equipped rooms and kiosks.

An illustration of the of the SCInet/I-WAY architecture overview is provided in Figure 5.1 on the following page. This figure provides a general idea of how the SCInet ATM cloud (network) accessed rooms and booths on-site, the I-WAY, the internet, and other sights. Figure 5.1 also includes the WAVE ATM cloud which provided connectivity to Kiosks, SP2, and the GII Room.

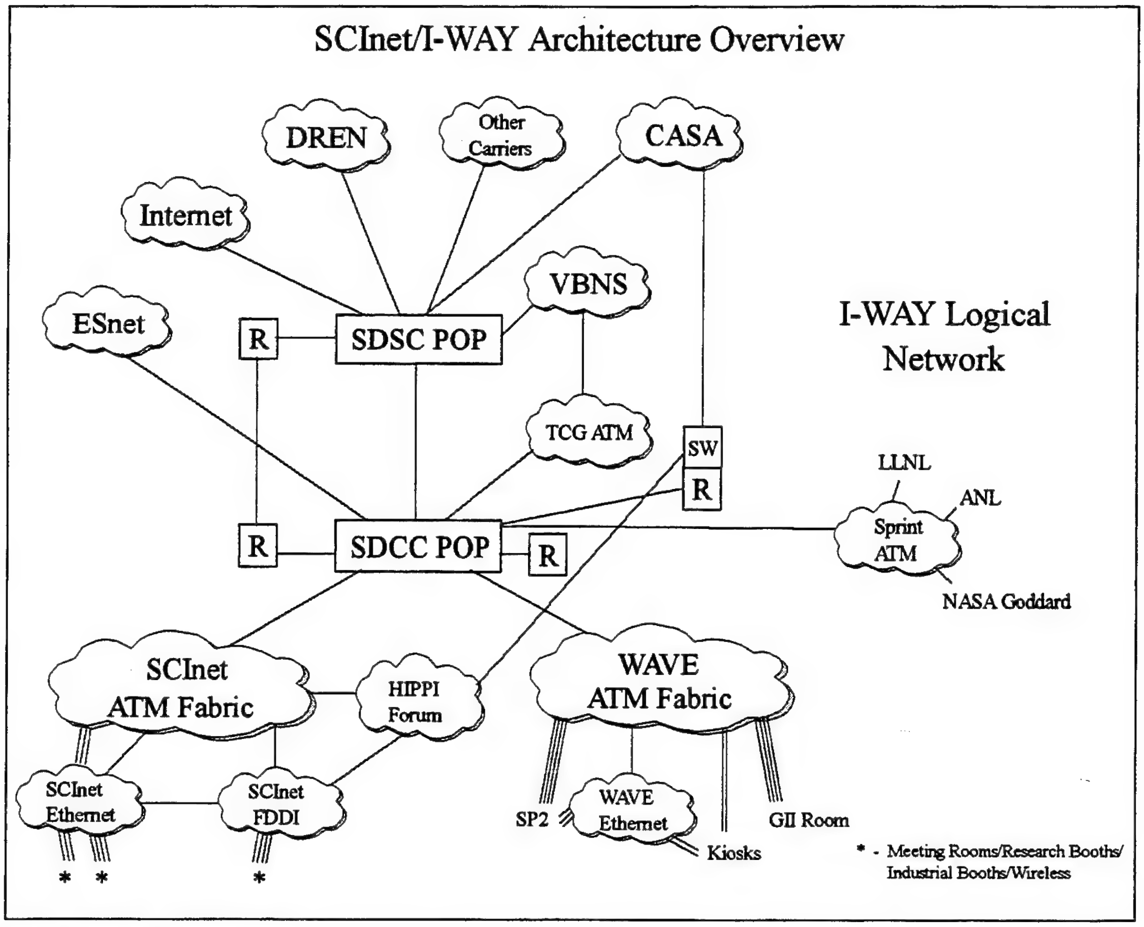

Figure 5.1 SCInet/I-WAY Architecture Overview

The SCInet and the WAVE ATM fabric obtained access to the I-WAY and the internet through the San Diego Convention Center (SDCC) and the San Diego State Supercomputing (SDSC) points of presence (POPs).

a. Hardware Configuration

As mentioned, ATM, FDDI, Ethernet, and Switched Ethernet technologies were used to provide network connectivity throughout the convention center. Many network administrators used wireless network connectivity to maintain the network. Because this thesis focuses of ATM technology, I have omitted detail discussions of how users and network administrators used FDDI, Ethernet, Switched Ethernet, and Wireless network technologies.

Figure 5.2 depicts the ATM switch fabric and physical connectivity of the switches. Four Fore BX and four Fore BXE200 ATM switches implemented the ATM fabric. The BXs supported one 16-port card. The BXE200s contained four slots of which each slot could have functioned as a single 16-port switch. As a result, each BXE200 was capable of functioning as four separate switches. However, only two of the BXE200s utilized four 16-port cards.

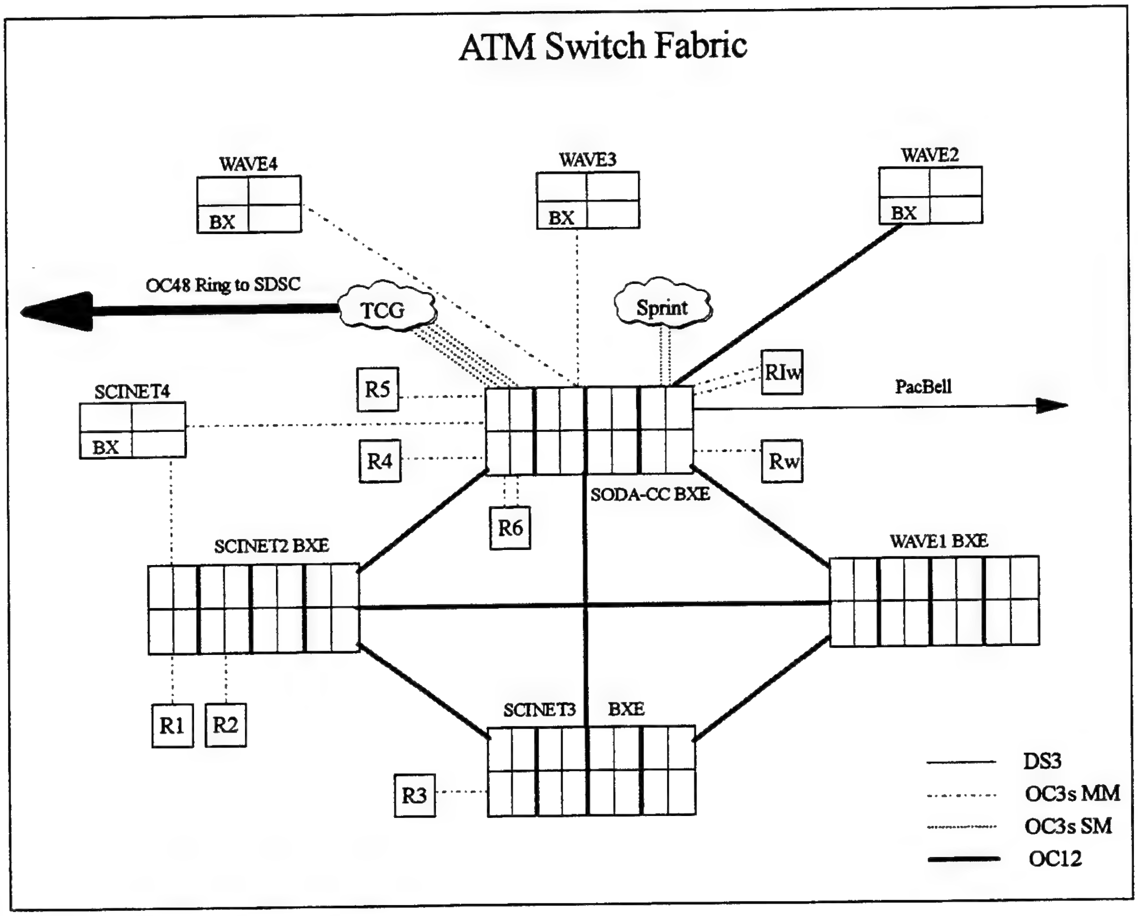

Figure 5.2 ATM Switch Fabric

The switches were connected using either single mode (SM) or multi-mode (MM) fiber. The speed of each fiber run ranged from 155 Mbps (OC3c) to 622 Mbps (OC12). As shown in the above figure, the fiber run between TCG and SDSC was capable of supporting throughput of up to 2.4 Gbps (OC48).

The SODA-CC BXE functioned as the central switch for connectivity to other switches, routers, and users. The users obtained I-WAY and internet access through the SODA-CC BXE. The routers provided connectivity to FDDI, Switched Ethernet, and Ethernet networks within the convention center. The remaining BXEs (WAVE1, SCINET2, and SCINET3) and the BXs (WAVE2, WAVE3, WAVE4, SCINET4) provided connectivity to the convention floor (booths, exhibits, conference rooms, meeting rooms, classrooms, etc.).

b. Software Configuration

The Fore BXE and BX switches were configured using software written specifically for them. One cannot guarantee that the software could run on a Cisco, Newbridge, or any other manufactured ATM switch. However, the software complied with ATM standards (UNI v3.0, etc.). By complying with the standards, the Fore switches were able to communicate with other brand name switches which also followed ATM standards.

The Fore switches were setup individually to ensure that they could function in a stand-alone mode prior to connecting them to form the ATM network. As the switches were connected physically, logical connections were formed to pass information. These logical links were created using virtual circuits (PVCs or SVCs). UNI v3.0 or Fores proprietary software (SPANS) was used to establish the virtual circuits. The network administrators used UNI v3.0 for any connection connecting a Fore and a non-Fore switch or device to ensure interoperability. SPANS was used when Fore switches or devices were connected.

3. Maintenance

SNMP (Simple Network Management Protocol) functioned as the network management application. This protocol ran under the Fores proprietary network management graphics user interface (GUI) tool, Foreview. Foreview, specifically designed for the Fore switches, allowed the network administrators to view each switch, down to the port level. Instead of having to physically stand in front of the switch to

determine the status of each port, the network administrator could determine the status of the port be clicking on a graphical representation of the port displayed on his workstation.

Foreview was also used to create, modify, or delete virtual paths and virtual channels. These paths, and channels were defined as either permanent (PVCs) or temporary (SVCs). When the PVCs were created, the port at the origin, destination, and intermediate ports, had to be identified. However, only the IP address of the origin and destination had to be identified when establishing a SVC.

C. SYSTEMS MANAGEMENT'S COMPUTER LAB LAN

1. Overview

Chapter IV provided a general overview of the Systems Management's three microcomputer labs which are located in Ingersoll Hall, rooms IN-158, IN-224, and IN-250. The lab in IN-158 is used for research; whereas, IN-224 and IN-250 are used for instructional purpose.

A Token-Ring network interconnects the three labs providing connectivity to two instructor computers, 40 user computers, ten servers, and an assortment of ancillary components. In addition to the Token-Ring network, the SM Department operates a 3Com 10 Mbps Ethernet LAN, a 230.4 Kbps AppleTalk LAN, and a PCLAN. The 3Com LAN is located in IN-224, and the AppleTalk LAN and PCLAN functions in IN-158.

ATM technology will now be used to redesign the Token-Ring and Ethernet LANs into one integrated LAN. The redesign is based on the PC LAN which was installed when this thesis was written. However, the redesign can easily adopt the upgraded PC LAN, a WFW configured network.

To redesign the LANs, physical and logical topologies, as well as the hardware and software configurations must be addressed. For simplicity, the hardware configuration will include the physical topology, and the software configuration will include the logical topology.

2. Hardware Configuration

a. ATM LAN

The ATM network, being designed, will conform to the ATM25 and ATM155 standards. The ATM Forum's Physical Layer Working Group voted to adopt 25.6 Mbps specification (the ATM25 standard) as the baseline for a medium-speed ATM physical connection specification (Duffy, C. A., 1995, p. 1). The new specification will allow the use of Category 3 UTP cable, and full-duplex 25.6 Mbps connectivity. This type of connectivity equates to approximately 50 Mbps throughput capability.

Not only can ATM25 standard function over UTP, it can also run over STP, coax, and fiber. However, most vendors are manufacturing ATM25 switches which connect PCs using UTP. STP, coax, or fiber is used to connect switches over long distances, or distances that exceed UTP limitations, and to obtain higher throughput.

The ATM 155 Mbps standard has been in existence for some time. Typically, fiber has been used to support this throughput rate. However, STP and Category 5 UTP are considered as viable and cheaper alternatives to fiber. Vendors are now producing ATM155 NICs which support STP and Category 5 UTP.

Figure 5.3, on the following page, depicts the redesigned network. The network has six segments (0ATM, 4ATM, 8ATM, 4EN, 4TR, and 8TR). The first number of each alpha-numerical designation, 0, 4, and 8, correspond to rooms IN-250, IN-224, and IN-158, respectively.

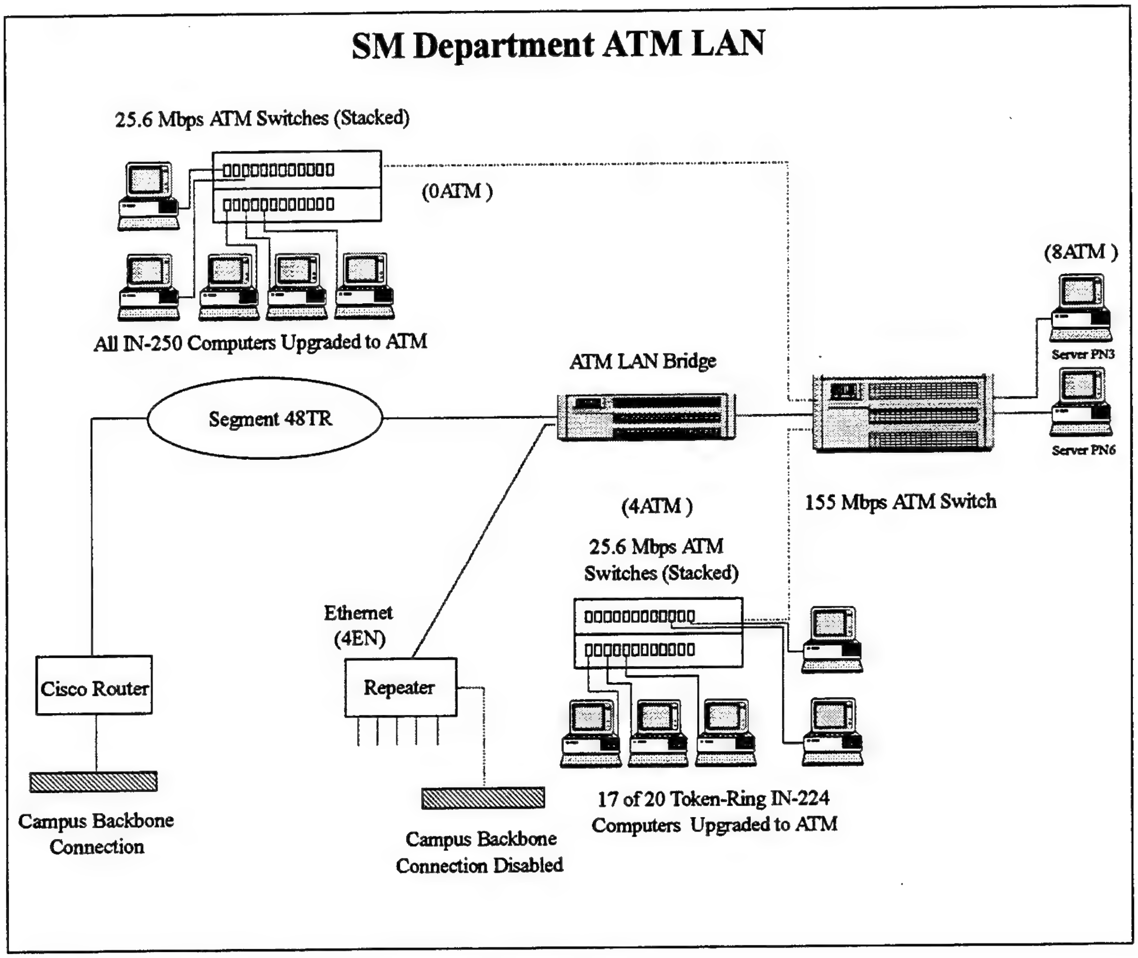

Figure 5.3 Systems Management Lab ATM LAN

Segments 4TR and 8TR (48TR) are interconnected to form a small Token-Ring that consist of nine computers. Three of the computers are located in IN-224; five computers are in IN-158. All of these clients will have access to the Pentiums servers in IN-158.

The proposed network consists of five ATM switches and an ATM LAN Bridge. Of the five switches, four are ATM25 switches (stacked in groups of two) and one is an ATM155 switch. The ATM LAN Bridge functions as a bridge to allow ATM, Token-Ring, and Ethernet technologies to operate in one integrated network.

Each ATM25 switch is capable of supporting up to 12 computers. Most vendors are designing ATM25 switches with 12 desktop ports. However, these switches are stackable using a Stacking Bus.

Because of the number of computers (user computers and servers) that will be upgraded to ATM, two or more stacked switches are necessary for IN-224 and IN-250. Figure 5.3 depicts only two stacked switches for IN-224 and IN-250. However, the number of stacked switches can be increased easily.

Only one switch, an ATM155 switch, is necessary in IN-158. This switch will provide connectivity to the servers, the ATM25 switches in IN-224 and IN-250, and the ATM LAN Bridge.

The 155 Mbps ATM switch in IN-158 will provide high speed access to the servers and the switches in IN-224 and IN-250. This configuration will greatly enhance the throughput capability of the integrated network, particularly under the new WFW network configuration. In the WFW network configuration, the applications (DOS- and Windows-based) will reside on the Pentium servers (PN3 and PN6) in IN-158. The 155 Mbps connections to these servers will provide the users faster response time.

Currently, Type 1 STP cable is in place to connect computers to the Token-Ring network. ATM25 is compatible with Type 1 STP cable, but most vendors are designing their switches to support UTP or Ethernet 10BaseT cable. IBM may be designing switches which are compatible with Type 1 STP cable. Should switches which are compatible with Type 1 cable be used, additional Type 1 cable may be required. In the current Token-Ring LAN, the Type 1 cable connects the computers to the appropriate MAU, and the MAUs are connected via Type 1 cable. In the case of ATM, each Type 1 cable link must run directly to a port in the switch. The switches in IN-224 and IN-250 will be stacked, and in a one location.

Another area that requires addressing should Type 1 cable be used is the connectors. Very few, if any, switches have ports compatible with IBM Token-Ring Adapters. Instead, the switches are compatible with RJ-45, coax, or fiber connectors. In order to marry the Type 1 cable (DB-9 connectors) to the switch port, an intermediate or connector conversion must occur.

Figure 5.3 also shows the fiber connectivity between IN-158, IN-224, and IN-250. Multi-mode fiber is the recommended medium because of the distance between the rooms, possibility of noise, and the 155 Mbps throughput. Many ATM25 switches

are capable of interconnectivity throughput of up to 155 Mbps. This throughput rate may exceed the Systems Management's requirement and the capability of the servers and PCs. However, the multi-mode fiber supports this throughput, and allows room for bandwidth growth. As faster servers and PCs are purchased, the throughput capability will be available to accommodate the increased demand for more bandwidth.

Multi-mode fiber, STP, or Category 5 UTP can be used to connect the servers and the ATM LAN Bridge in IN-158 to the ATM155 Switch in IN-158.

b. ATM Segment 4ATM (IN-224)

The redesigned network in IN-224 uses ATM, Token-Ring, and Ethernet technologies. Because IN-224 functions as the networks lab, the interconnectivity of the three network technologies provides students and staff hands-on experience in an integrated environment.

In this environment, the Ethernet network (4EN) will remain intact. The only addition would entail linking the repeater to the ATM LAN Bridge. This attachment may require the use of one of the repeater ports. The ATM LAN Bridge must be capable of supporting a coaxial or RJ-45 connection. However, a coaxial cable is recommended because of the distance between the Repeater and the ATM LAN Bridge. The bridge will be located in IN-158.

The Ethernet campus backbone connection can be disabled or remain enabled to function as a backup to the Token-Ring campus backbone connection through the Cisco router. However, only one backbone connection is needed on the integrated network.

The Token-Ring Segment 4TR is a much smaller version of the existing 4TR segment. This redesigned segment is comprised of one MAU and three computers. However, 4TR is expandable up to six computers. One port is required for backbone connectivity. A second port is necessary to link the MAU to the ATM LAN Bridge. The RI and RO ports are used for connectivity to the MAU in IN-158.

Figure 5.4, next page, depicts the 4ATM Segment. This segment consists of two ATM25 Switches for connectivity to a maximum of 24 computers. However, 17

of the 20 computers are designated to be upgraded to ATM. This leaves seven ports that are available for growth.

Figure 5.4 also shows two new servers (Novell Server PN1 and Print Server) that will be upgraded to ATM. These servers replaced TN6M and TN3 during the WFW upgrade.

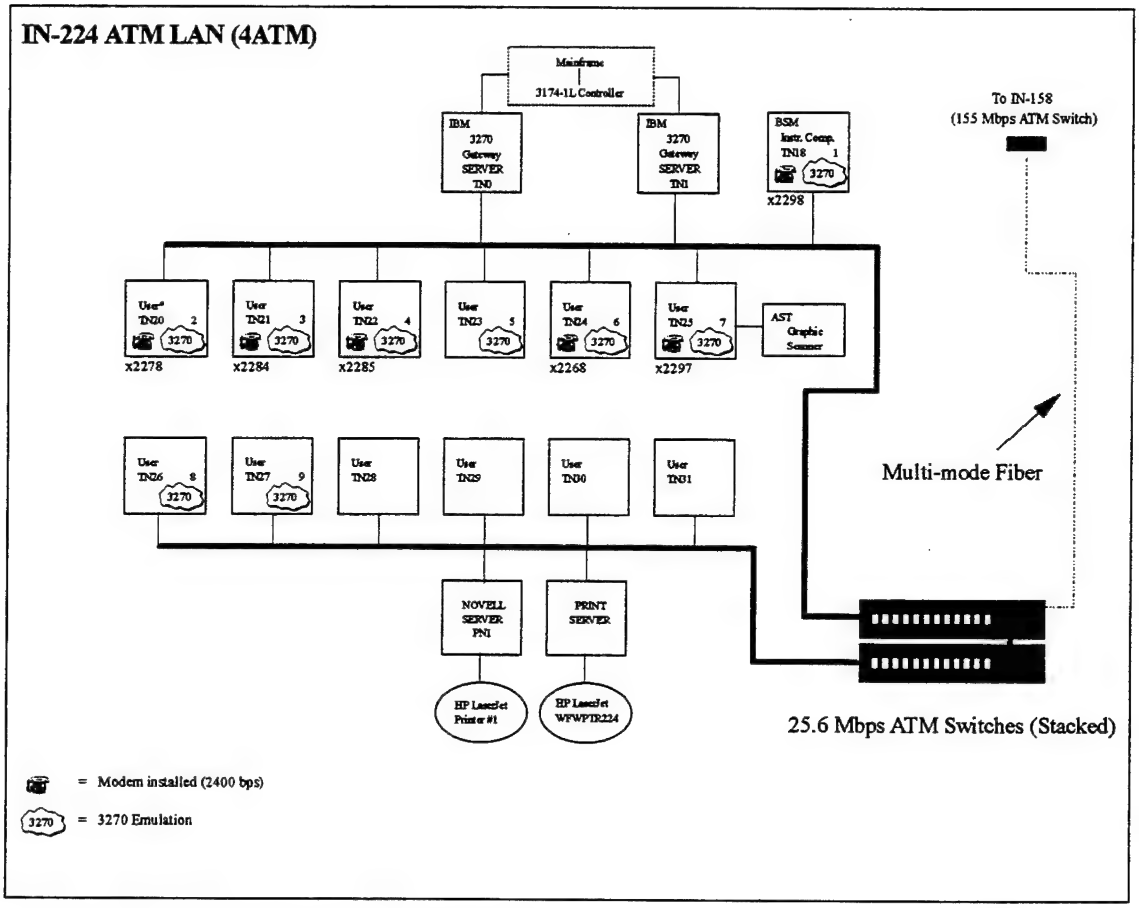

Figure 5.4 IN-224 ATM LAN (4ATM)

The two ATM25 switches that will service the 17 computers will be stacked on top of each other using the Stacking Bus Option. The Stacking Bus Option allows a group of ATM switches to be stacked on top of one another and function as one "combined" switch.

Existing peripheral equipment (printers, a graphics scanner, an external CD-ROM reader, a video projection system, and internal modems) is included in the

proposed designed. These peripherals are connected to the same server or user computer that they are currently connected too in the existing Token-Ring and Ethernet LANs.

Computers that currently have 3270 emulation capability will not loose this capability in the ATM LAN. These computers will continue to have the ability to connect to the Computer Center mainframe via the two 3270 Gateway Servers (TN0 and TN1). These servers will continue accessing the mainframe through an IBM 3174-1L Controller.

c. *ATM Segment 0ATM (IN-250)*

ATM Segment 0ATM interconnects one 486 server, an instructor computer, and 22 user computers. Two switches are stacked using the Stacking Bus option. As with the 4ATM segment, each computer requires a dedicated STP or UTP cable run. Figure 5.5, below, provides a diagram of how the computers would be physically connected in the 0ATM segment.

Unlike the original Token-Ring Segment 0TR (IN-250), Servers N3, N6, and N17 are not used in Segment 0ATM. These servers were not included in the WFW upgrade. However, Print Server WFWPRT#1 was apart of the WFW upgrade. This server will provide print services.

Each computer on the 0ATM segment will use WFW and access DOS- and Windows-based applications from the Pentium servers in IN-158. The stacked ATM switches in IN-250 are connected to the 155 Mbps ATM switch in IN-158 by a multi-mode fiber cables. The connection supports speeds up to 155 Mbps between the stacked 25 Mbps switches in IN-250 and the 155 Mbps switch in IN-158.

The instructor computer (N9) and six user computers (N10 through N15) keep their 9600 baud internal modem configuration. As with the current LAN, these modems will allow access to the Computer Center mainframe and the Sun Workstations. The modems will also allow access to the ATM network from remote locations.

All 24 desktop ports of the stacked ATM switches are designated for use. Though the stacked switches are at maximum capacity (physically), a third ATM25 Switch (same vendor) can easily be added to the stacked switches to allow growth for 12 additional computers.

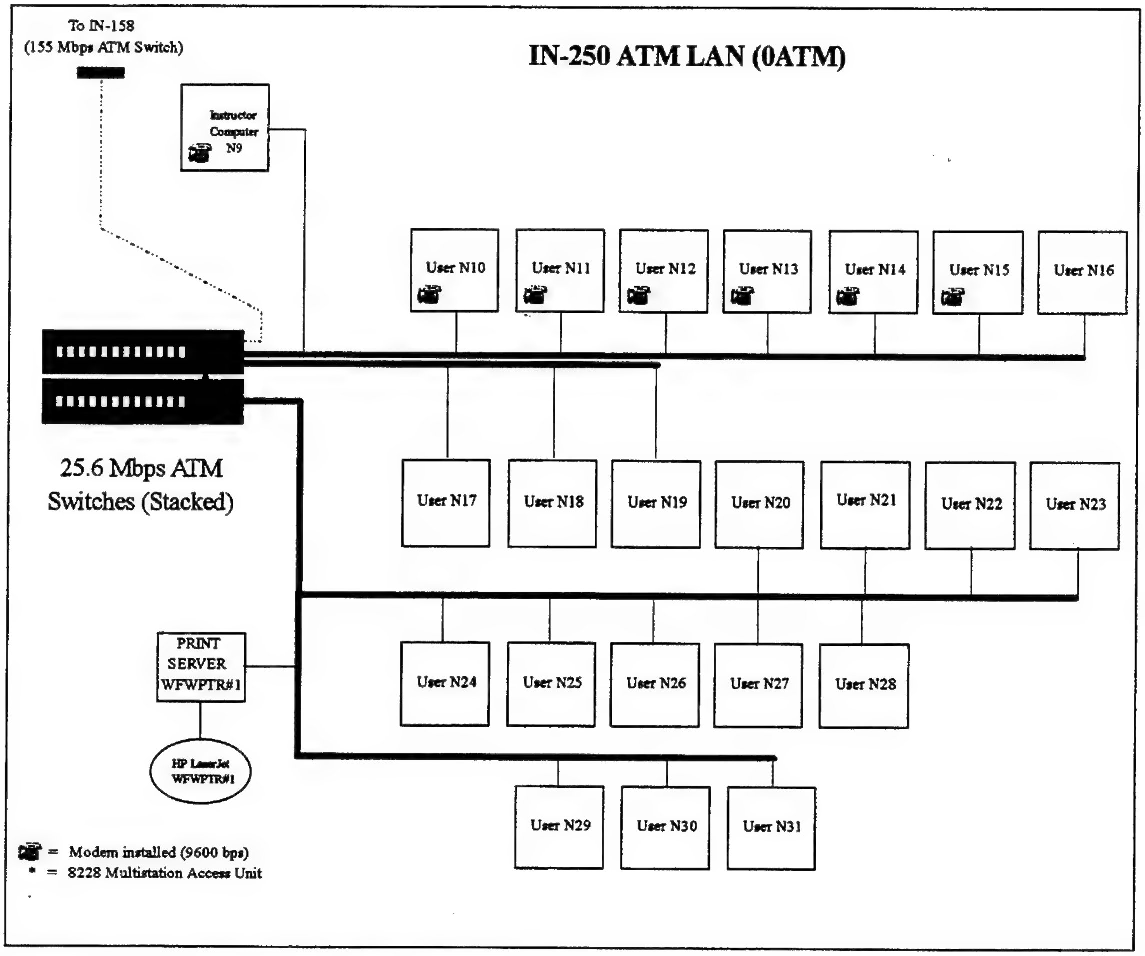

Figure 5.5 IN-250 ATM LAN (0ATM)

d. *ATM Segment 8ATM (IN-158)*

IN-158 is the Software Metrics Lab. The redesigned integrated network in this dedicated lab comprises ATM and Token-Ring technology. Figure 5.6, on the following page, illustrates how the two networking technologies are integrated into one network. Regarding the ATM technology, a 155 Mbps ATM switch and an ATM LAN Bridge is used. The high-speed switch provides 155 Mbps connectivity to two Pentium Servers, the Stacked ATM25 Switches in IN-224 and IN-250, and the ATM LAN Bridge. The Pentium Servers, and the ATM LAN Bridge can be connected to the high-speed switch using either multi-mode fiber, STP, or Category 5 UTP cable. Vendors claim the Category 5 UTP cable supports 155 Mbps throughput rates. However, very few network administrators used this type of cable when upgrading to 155 Mbps ATM LANs. To

reduce risks of implementing new technology, Category 5 UTP should not be considered as an alternative.

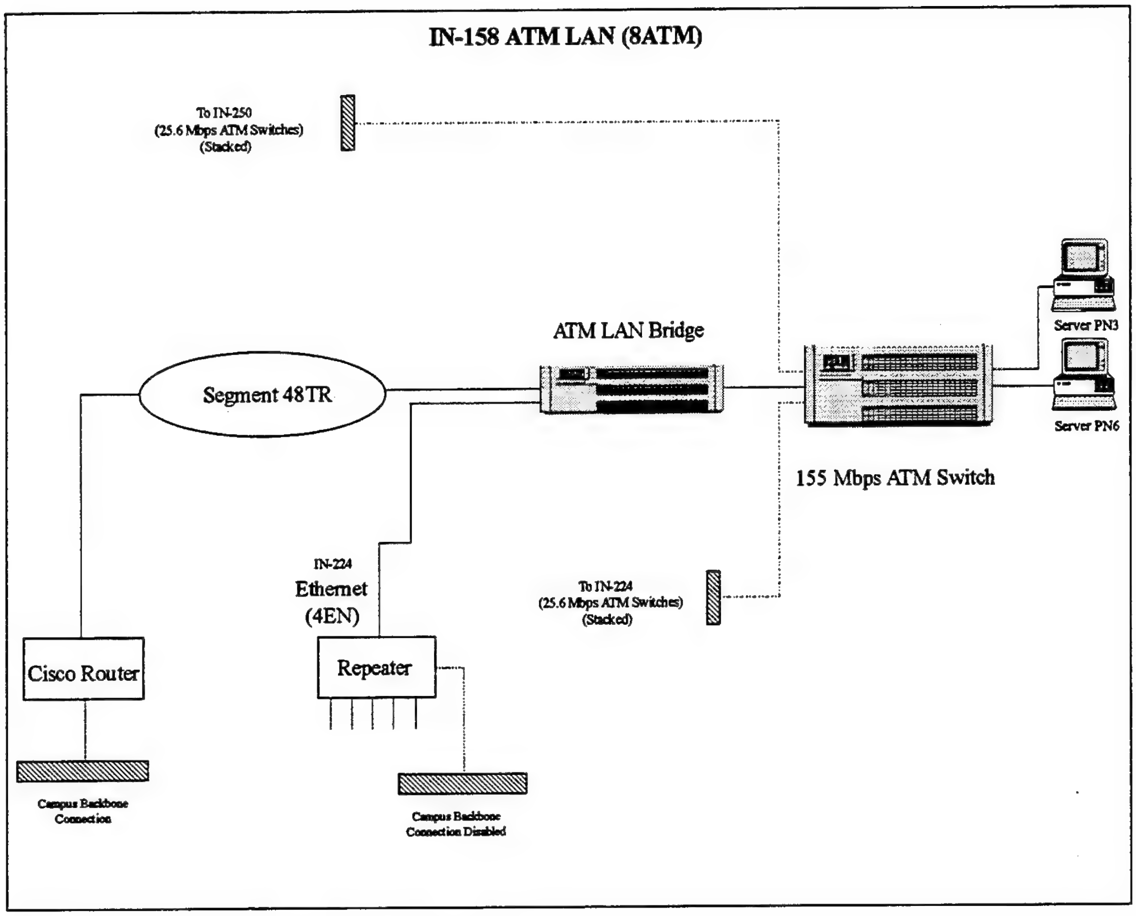

Figure 5.6 IN-158 ATM LAN (8ATM)

The ATM LAN Bridge provides connectivity to the ATM, Token-Ring, and Ethernet segments of the integrated network. This connectivity will allow the computers in the various segments to communicate and share resources though they may use different networking protocols.

The Pentium servers (PN3 and PN6) will continue providing DOS- and Windows-based application services to users in IN-250. These servers will also continue running WFW. As additional pentium servers are added to the network, they should be

connected to the high-speed switch on Segment 8ATM. This will provide faster response time to the users.

The 486 server (TN4) and the five Token-Ring computer will remain on Segment 8TR. One MAU is adequate to provide connection to the six computers. One port on the MAU will be used to link Segment 8TR to the ATM LAN Bridge. Server TN4 can continue providing DOS- and Windows-based application services and print services to user computers in IN-158. However, as faster servers are connected to the ATM155 switches, the applications and print services can be transferred to the faster servers, thus providing faster and better services to Software Metrics Lab users.

The AppleTalk LAN and the PCLAN were not included in the integrated network in IN-158. Because the AppleTalk LAN and the PCLAN are proprietary and are in compliance with the IEEE 802 standards, very few vendors are producing products that are interoperable with these LAN protocols. As a result, I recommend that these LANs remain separate, and not be incorporated in the integrated network. If the LANs were included, the integrated network may become proprietary itself.

e. Hardware Requirement

Based on the physical design of the SM Lab ATM LAN, the hardware requirements to implement the LAN are provided in the table on the following page. The table provides the items, quantity, and special comments.

As mentioned in the previous sub-section, UTP, STP, or Type 1 cabling, or a combination of these cable types can be used to connect the computers to the switches. However, for consistency and a more homogeneous network, it is better to use one type of cabling, either UTP or STP, to provide connectivity to each computer (server, instructor and user computers) connected to the ATM25 switches. Multi-mode fiber, or STP should be used for ATM25 Switch - ATM155 Switch, ATM155 Switch - ATM LAN Bridge, and ATM155 - Pentium Server links. Fiber and STP support the 155 Mbps throughput rate better than UTP.

Type 1 cabling is a possible option, particularly since this type of cable is currently in place, but few vendors are manufacturing NICs which are compatible with this cable (DB-9 connector). Also, additional Type 1 cable and connectors are required to extend the cable runs from each computer to the centralized switches (stacked).

Item	Qty	Comments
ATM155 Switch	1	
12 Port ATM25 Switch	4	Most ATM25 Switches are configured with 12 ports. If an ATM25 Switch is configured with 16 ports, four switches are still needed.
ATM LAN Bridge	1	Should support Token-Ring and Ethernet Connections
Stacking Bus Option	2	For Switches in IN-224 and IN-250.
155 Mbps Line Interface Cards	9	6 for ATM155 Switch. 2 - one each for the ATM25 Switch 1 for the ATM LAN Bridge
25.6 Mbps Line Interface Cards	0	Typically, the ATM25 Switches require no Line Interface Cards for connection to computers. Instead, these switches are shipped with RJ-45 ports which are ready for connectivity. However, if there are requirements for specific configurations (certain cable or connectors), the ATM25 Switch may require 41 Line Interface Cards.
25.6 Mbps Network Interface Card	41	For Computers designated for connection to the ATM25 Switches.
UTP or STP Cabling		If all cabling replaced.
Type 1 (STP) Cabling		If existing Type Cable is used.
Coax		Backbone Connectivity
Multi-mode Fiber Cable		Switch-Switch and Pentium Server - Switch Links
Connectors		
UTP, STP, Type 1		
Coax	2	Backbone Connectivity
Multi-mode Fiber	12	Switch-Switch , Pentium Server-Switch, and ATM LAN Bridge-Switch Links

Table 5.1 ATM Hardware Requirements

Regardless of the type of cabling that would be used to provide connectivity, the appropriate NICs must be installed in the each computer. ISA or EISA

NICs are necessary for the 486 DX 33 MHz computers. The Pentium computers can use PCI configured NICs.

3. Software Configuration

a. Server and User Computer Configuration

In order for ATM technology to function properly with any network, some form of change in the software configuration must occur in network servers and the user computers. Generally, these changes may encompass the replacement, upgrade, or modification of current network drivers (Token-Ring, Ethernet, etc.). These drivers are loaded into memory during the boot process to establish a logical connection between the computer and the entire system. The CONFIG.SYS file in the user and instructor computers contains the drivers. The servers also have a special file that is executed every time they are booted to create a network environment (Token-Ring, Ethernet, etc.) after loading appropriate network drivers into memory.

The NIC drivers for the PCs and the servers must be compatible with the network operating system (NOS). This is also true with ATM network drivers. Many vendors are currently manufacturing ATM NIC drivers that function with WFW, Windows NT, and Netware. In some cases, the ATM drivers will not be compatible with all three. Therefore, if an office has a network which has all three of the these networks, different NICs from different vendors may be required. If so, this may lead to compatibility problems between the cards and the ATM switches if the vendors do not adhere to the ATM Forum standards.

b. Switch Configuration

Not only must appropriate network drivers be used to ensure a functioning ATM network; the ATM switches must also be configured properly. The switches must be configured to run as an IP network or a network using LAN Emulation. In the case of the SM Lab LAN, LAN Emulation should be used. The LAN Emulation protocol defines the mechanisms to emulate either an IEEE 802.3 Ethernet or an 802.5 Token-Ring LAN.

As discussed in Chapter II, the LANE protocol defines the operation of a single emulated system LAN (ELAN). Multiple ELANs may coexist simultaneously on a single ATM network since ATM connections do not collide. A single ELAN emulates either Ethernet or Token-Ring and must consist of LECs, a LES, BUS, and LECS. Chapter II, Section C.3 provided a detail description and function of these components.

Based on the configuration of the SM Department Lab Network when this thesis was written, and the proposed design of the SM Department Lab Integrated Network, four ELANs are recommended. The former 0TR Segment, the new 0ATM Segment, encompasses ELAN#1. ELAN#2 (IN-224) comprises of the smaller 4TR Segment, and the computers that are upgraded to ATM (Segment 4ATM). The Ethernet LAN (4EN) in IN-224 is ELAN#3. This LAN will remain intact and be connected to the ATM LAN Bridge. ELAN#4 includes a smaller 8TR Segment of the Token-Ring Network. The Pentium Servers will be a member of each ELAN because they provide application services to each ELAN. The ATM switches in the various ELANs will function as the LES(s), BUS(s), and LECS(s). Figure 5.7, on the next page, shows an illustration of the ELANs.

Not only must the ATM Switches support LAN Emulation, the ATM LAN Bridge must also support LAN Emulation. Without this capability, the bridge will be unable to forward information to the correct ELAN or user.

Appendix B provides information on LAN Emulation products (Hold, D. F., 1995, p.1).

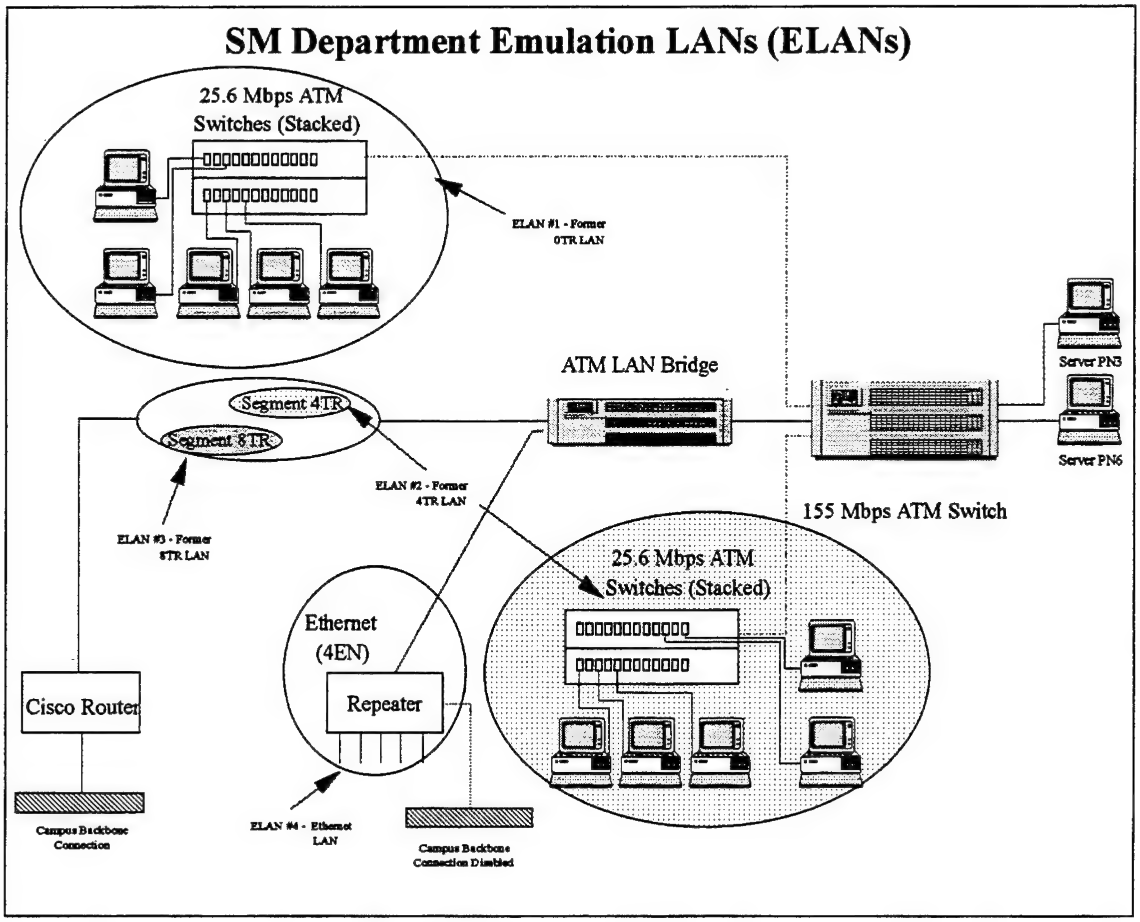

Figure 5.7 Systems Management Emulated LANs

c. *Virtual Connectivity*

Chapter II also discussed PVC (Permanent Virtual Circuit) and Switched Virtual Circuit (SVC) connections. PVCs are permanent or dedicated connections. Whereas, SVCs are established for information transmissions and torndown after all information has reached the receiving end.

In the case of the Systems Management Lab ATM LAN, PVCs should be used for connectivity to and from the servers and switch-to-switch connectivity. The PVC (full-duplex) throughput should be 25.6 Mbps and 155 Mbps, each way, for server and switch-to-switch connectivity, respectively. The Pentium Servers connected to the ATM155 Switch should have 155 Mbps connections. The other servers should have 25.6 Mbps connections. SVCs should be used for user and instructor computers. Figure 5.8 illustrates the proposed virtual connectivity for the ATM LAN.

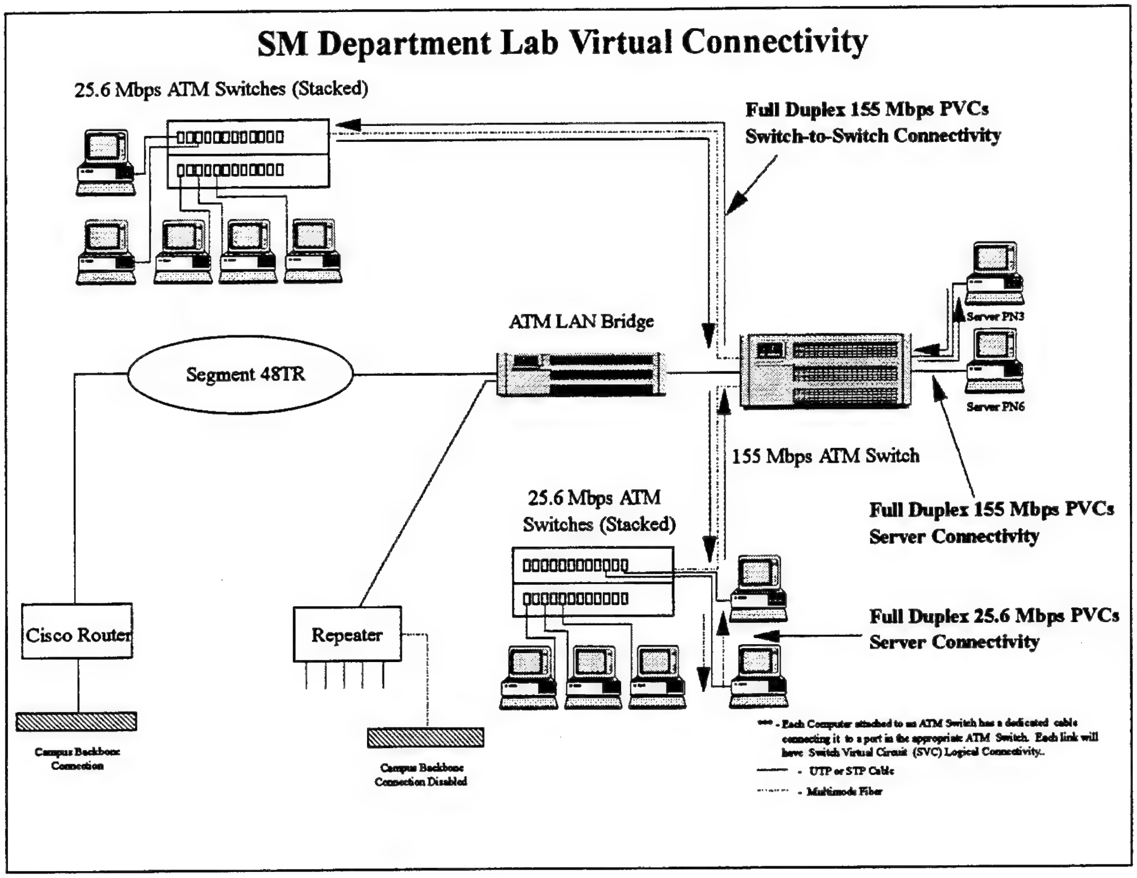

Figure 5.8 Systems Management Lab Virtual Connectivity

By establishing PVCs for the servers and switch-to-switch connections, and SVCs for user and instructor computers, minimum dedicated virtual connections would be used. This reduces inefficient use of bandwidth. If PVCs were used for the user and instructor computers, each PVC would have to be from the port servicing the computer to the port servicing the server. If the computer communicates to more than one server, then additional PVCs are required. As one can see, if PVCs were used, network management would be drastically increased. Also, more time is required to establish and maintain PVCs.

d. Software Requirement

Table 5.2 provides a list of essential software to ensure the proper functioning of the SM Lab ATM LAN. Each room should require ATM Switching

software to operate their appropriate segment of the LAN. The software should have drivers for Novell Netware NOS, WFW, and Windows NT. These drivers will allow the SM Department Lab Network to operate in an ATM environment as it migrates from a PC LAN network to a WFW/Windows NT network.

The stacked switches in IN-224 and IN-250 should each require the Stacking Bus Module. The Module should allow the use of one copy of ATM Switching software instead of the actual number of "stacked" switches.

The ATM Switching software drivers for the ATM25 and ATM155 Switches should be compatible with the 25.6 Mbps NICs, the 155 Mbps Line Interface Cards. To ensure switch, driver, and card compatibility, the same vendors should produce the 25.6 Mbps NICs, the 155 Mbps Line Interface Cards, switches, and ATM LAN Bridge. If the same vendor does not produce these items, the group of vendors that manufactures the software and drivers must adhere to ATM standards to ensure compatibility and interoperability.

Item	Qty	Comments
ATM Switch Software		Operating System for the Switches must have drivers for Netware, Windows for Workgroup, and Windows NT. The Switch Software must support LAN Emulation. This requirement is also applicable to all Drivers.
Stacking Bus Module	2	For Switches in IN-224 and IN-250.
25.6 Mbps NIC Drivers	41	For Switches.
155 Mbps Line Interface Drivers	7	Switch-Switch Connectivity.
ATM LAN Bridge Software		Must be compatible with the switch software.
LAN Emulation Software		All switches, the ATM LAN Bridge, and drivers must have LAN Emulation capability.

Table 5.2 ATM Software Requirements

The LAN Emulation software and drivers are of utmost importance to ensure that the applications on the current SM Department Lab Network are functional in an ATM environment. As discussed in Chapter IV, Token-Ring and Ethernet are the primary network technologies in the SM Department Lab Network. The applications are

designed to run of over these shared medium networks. Standard software interfaces or drivers such as Novell's ODI or Microsoft's NDIS interface support these applications.

ODI and NDIS provide network transport services to the application software that operates in both the server and the client workstation, and these services reflect the underlying nature of the LAN technology. Today's Token-Ring and Ethernet LANs provide connectionless "best effort" delivery of variable length packets which are addressed to a specific physical interface(s). These LAN technologies also support broadcast and multicast packet delivery, whereby a packet with a certain address will be delivered to all, or a subset of , the workstations on the network.

The higher layer of the communications software in LAN end stations, including the client "shell" and the server operating system, have evolved around this functionality. (Taylor, Martin. 1995, p.9)

ATM networks operate differently than today's traditional networks. ATM is connection-oriented, in which a connection is established before any information is forwarded to the destination. Also, data is fixed length, and is sent to the appropriate destination(s) by the use of virtual channel identifiers instead of addresses to a physical interface card. Last, but not least, ATM does not provide a true equivalent of broadcast and multicast services offered in today's LANs.

LAN Emulation is the "solution" to the problem of running existing LAN applications over an ATM network. This procedure defines a "LAN Emulation Client" (LEC) process to function in each station, which adapts the connection-oriented cell transport service provided by ATM to the connectionless packet transport service demanded by the applications. Figure 5.9 shows how LAN applications run on an ATM network. (Taylor, Martin. 1995, p.9)

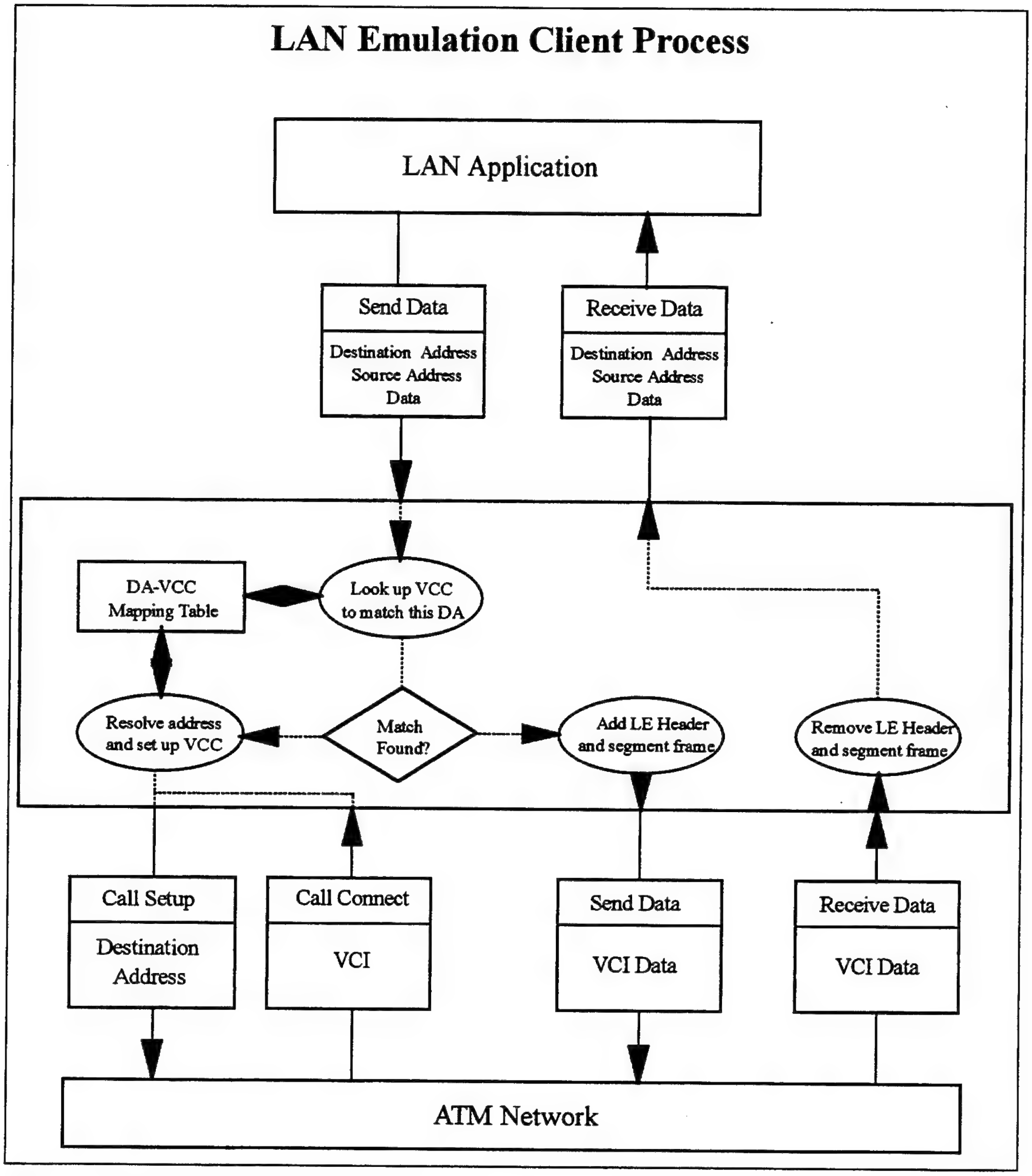

Figure 5.9 LAN Emulation Client Process

As depicted in the above figure, the LEC process handles the transmission and receipt of LAN packets from the ATM network, as follows (Taylor, Martin. 1995, p.9-10):

- When a client request to transmit a packet, the LEC process receives packet's LAN destination address and determines the ATM station address. If no virtual channel connection is set to this address, the LEC request that the ATM switch establish a connection. Once the connection is made, the LAN packet is segmented into ATM cells and transmitted over the connection.

- If a client or server request to transmit a broadcast packet, the LEC segments the packet into cells and transmit the cells to the Broadcast and Unknown Server (BUS). The BUS maintains a list of all the stations on the ATM LAN and sends the cells to all stations on the list. As a result, the appropriate stations receive the broadcast packet.

- When an end station or server receives a stream of ATM cells, the LEC re-assembles the cells, re-creates the original LAN packet, and forwards the packet to the application.

The LEC process uses one of the standard network software interfaces (ODI or NDIS) to communicate with the end station's or server's application software. In actuality, the LEC emulates a standard ODI or NDIS network adapter card driver, tricking the end station software into believing that it is communicating with a Token-Ring or an Ethernet adapter. Manufacturers incorporate the LEC process into the driver software that shipped with the ATM adapter. As a result, it is a simple process to install an ATM adapter complete with LAN Emulation in a server or client software environment. (Taylor, Martin. 1995, p.9)

4. LAN Management

Every network, regardless of size or type, requires network management. This will be particularly true for the proposed ATM LAN. However, to properly maintain the ATM LAN, personnel, personnel training, documentation, and maintenance tool are required. The subsequent sub-subsections address these requirements.

a. Personnel and Training Requirement

Two or more people may be required to maintain the proposed integrated network. These people will be responsible for the upkeep (adding, deleting, and modifying virtual and physical connections) of the network. They will also perform upgrades to the ATM Switch software as new ATM standards are released, and upgrade user, instructor, and server computers.

The current LAN administrator is very familiar with existing LAN technology. However, he will require ATM training, and possibly training in the installation of fiber, and UTP, or STP cable.

b. Documentation

Documentation is of utmost importance when implementing the design of the ATM network. As with the Token-Ring and Ethernet networks, documentation of physical connections is necessary. However, documentation of logical links is very critical for the integrated network. Though all physical connections may be up, information will not reached the proper destination unless the correct logical connection is established. If information is not reaching the right destination, and all physical connections are established, the administrator's next step is to ensure that the switches establish the proper logical connection. This is done by verifying the virtual connection. This task may be very difficult to perform without proper physical and logical documentation, particularly in a large network.

c. Maintenance Tools

Graphics user interface (GUI) maintenance tools will greatly assist the LAN administrator in maintaining the ATM network. However, these tools can be very expensive. A small ATM network may not require a GUI maintenance tool. The text editor should be sufficient for the small network. Because the SM Lab Integrated Network will consist of 10 servers, 43 clients, and backbone connectivity, a GUI maintenance tool may be necessary. This tool must be compatible with the ATM switches.

Most ATM GUI maintenance tools run on UNIX platforms. However, manufacturers have begun producing tools that can run on a Windows NT platform. This is a great stride forward for ATM25 networks, since most PC networks are Windows-, Windows NT-, or DOS-based. The Windows NT GUI tool would greatly assist the LAN administrator in maintaining the proposed integrated network.

D. CHAPTER SUMMARY

This chapter discussed the design of an integrated network comprised of ATM, Token-Ring, and Ethernet technologies. However, before covering the design of the proposed integrated network, the chapter covered the ATM network installed for the Supercomputing 1995 conference in San Diego, CA. The Supercomputing 1995 conference network provided me a better understanding of how an ATM network is designed and implemented, both physically and logically. As a result, this knowledge greatly assisted me in the design of the proposed SM Lab Integrated Network.

Several key areas were covered the physical and logical design of the recommended network. One in particular was the use of one vendor for the integrated network. To ensure compatibility of the network, one vendor should manufacture the switches, an ATM LAN Bridge, LINF cards, and NICs. The vendor should also be an active member of the ATM Forum, adhere to ATM standards, and understand ATM technology and its evolution.

Not only are the switches, ATM LAN Bridge, LINF cards, and the NICs crucial in the physical implementation of an ATM network, but the cabling plant is also critical. Over 90% of the SM lab network cabling plant is Type 1 (STP). Though ATM runs over Type 1 cable, very few vendors produce cards which are compatible with Type 1 cable. Mainly STP, UTP, coax, and fiber are the forms on which cable vendors are focusing.

To ensure compatibility and not be left with few vendors to procure ATM hardware from, UTP and fiber are the recommended choices of cable for the Systems Management Lab Integrated Network. UTP should be used to connect the user and instructor computers and the servers to the ATM switches. Multi-mode fiber should be used for switch-switch, ATM LAN Bridge-switch, and Pentium Server-switch

connectivity. The fiber is recommended for these connections because of 155 Mbps throughput rate, distance (switch-switch connectivity), and the possibility of noise interference.

The ATM switches recommended for the lab network are based on the ATM25 and ATM155 technology. This technology is suitable for the lab network because ATM25 was designed for PC desktop networks. The ATM25 switches should comply with ATM standards, particularly LAN emulation and UNI 3.0 standards. LAN emulation will allow the ATM network function like a Token-Ring or Ethernet network. The UNI 3.0 standard allows the use of SVCs and PVCs.

The ATM155 Switch will provide high-speed data rates between the switches, and to the ATM LAN Bridge and Pentium Servers. The ATM155 Switch must also comply with ATM standards..

The switch software must not only address these standards, but it must also use drivers for Novell Netware, WFW, and Windows NT. The LINF cards and NICs for the computers must also use compatible drivers. The drivers for the NICs must be loaded on each computer that will be connected to the ATM switches

If all the hardware (ATM switches, cabling, LINF cards, NICs, and computers) are properly connected, the ATM network is still not guaranteed to function properly. Both physical and logical connectivity must be established. Logical paths (virtual circuits) must be configured after physical connectivity has been established.

Other areas of concerns are personnel, training, documentation and maintenance. These areas, and the proper physical and logical connectivity of the ATM network are a must to efficiently and effectively run the integrated network.

VI. MIGRATION OF SM DEPARTMENT LAB LAN TO AN ATM LAN

A. PURPOSE OF CHAPTER

The purpose of this chapter is to discuss a migration strategy to upgrade the existing SM Department Networks Lab from Token-Ring and Ethernet technologies to an integrated network encompassing not only ATM technology, but also Token-Ring and Ethernet technologies. Because of the higher throughput rates ATM offers, and the greater data rates users will expect once a computer is upgraded to ATM, this chapter will also discuss the speed limitations of existing computers when they are connected to an ATM switch.

B. INTEGRATED LAN MIGRATION STRATEGY

1. Overview

The redesigned SM Department Networks Lab LAN discussed in the previous chapter should not be implemented in one phase. A one-phase implementation will produce an extended period of downtime, administrative and maintenance training, and a tremendous technology risk and monetary investment. Instead, the migration must be done in phases to minimize network disruption, maintenance headaches, technology risks, and costs. Each phase should leverage as much of the existing technology (hardware and software configuration) as possible, and preserve the network infrastructure (Lindsay, S., Rosenblum, D. and Walleigh, W., 1995). Other factors to consider when migrating to a high-speed network include:

- Existing network technologies;
- Budget;
- Where network bottlenecks occur;
- Type of cabling available;

- Types of future application for the LAN;
- Timeframe considerations (Carr, J., 1995, p. 60).

There are many high-speed network technologies available in the marketplace which may be used to upgrade the SM Department Networks Lab LAN. These technologies include Fast Ethernet (100baseT), 100VG-AnyLAN, FDDI, and ATM. However, this thesis focuses on designing an ATM LAN that would possibly be an upgrade to the current LAN. Therefore, I will only discuss a possible migration strategy using ATM technology.

The availability of funds will determine how quickly a high-speed networking technology will be phased into an existing network. Even if a vast amount of funds were available, bottleneck areas should be considered as the first area to migrate to high-speed pipes. This approach will minimize disruption to the network, the procurement of new hardware and software, and improve overall performance of the network.

The migration strategy should also use as much of the existing cabling plant as possible to minimize cabling cost (material and installation). The other two factors, types of future applications and timeframe considerations, will also determine how quickly or slowly one would implement a high-speed network technology. In the case of the SM Department Networks Lab LAN, these two factors can be used to extend the migration to phase in ATM technology. The current network is only used for data (text) transfer and not to transmit or receive voice, video, and images.

To devise a migration strategy for the SM Department Networks Lab, budgetary, bottleneck areas, and cabling plant availability and compatibility are primary concerns. These concerns are used in creating a six phase approach to provide ATM services to the desktop. These phases are discussed in the subsequent subsections. The network administrator can combine several of the phases if additional funds are available or time becomes a critical factor.

2. Phase I: Upgrade Pentium Servers (IN-158) to ATM

The first phase of the SM Department ATM LAN evolution is the conversion of the Pentium Servers (PN3 and PN6) in IN-158 from 16 Mbps Token-Ring to 155 Mbps ATM. These servers are converted first because excess traffic on a Token-Ring LAN creates throughput problems which causes the servers to respond sluggishly or inconsistently to application requests. This may cause sessions to die while waiting for acknowledgments from a far end of a connection. As a result, user productivity degrades.

The converted servers are connected to a 155 Mbps high-speed ATM Switch. This switch will be connected to an ATM LAN Bridge. The primary purpose of the bridge is to provide connectivity to the ATM Switch and the existing Token-Ring network. Therefore, no changes are required to the existing Token-Ring infrastructure, and users will have the ability to access the DOS- and Windows-based applications on the Pentium Servers using ATM technology. Also, backbone connectivity remains intact. Figure 6.1 illustrates the Phase I implementation.

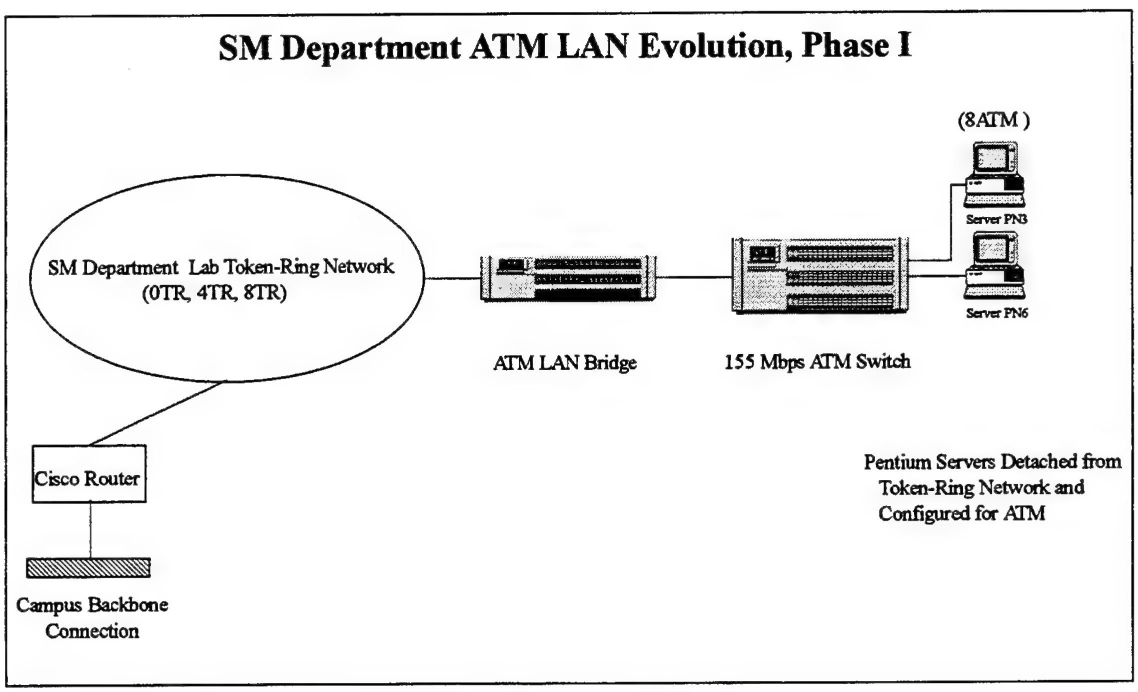

Figure 6.1 SM Department ATM LAN Evolution, Phase I

3. Phase II: Integrate the Ethernet LAN (4EN) into the Network

As shown in Figure 6.2, next page, the only difference between Phase I and Phase II is the connection of Segment 4EN (Ethernet) to the ATM LAN Bridge. This addition will require a coaxial cable run from IN-224 to IN-158 to physically connect the Repeater to the bridge. Both the repeater and the bridge must be compatible in order for the connect to function properly.

While running the coaxial cable from IN-224 to IN-158, the cable installer may also want to run a multi-mode fiber cable. The multi-mode fiber will be required to connect an ATM25 switch to the ATM155 switch in IN-158 during Phase IV.

One key advantage about this phase is that Ethernet users will have the ability to access applications on the various servers on the network. Also, in the WFW environment, the 4EN users will have peer-to-peer, and peer-to-server capabilities. These new capabilities are much more than the current functionality of the 4EN users. The 4EN users can only perform TCP/IP functions, via the Ethernet campus backbone connection, with the Token-Ring users.

Regarding the Ethernet campus backbone connection, this connection will remain in place during this phase.

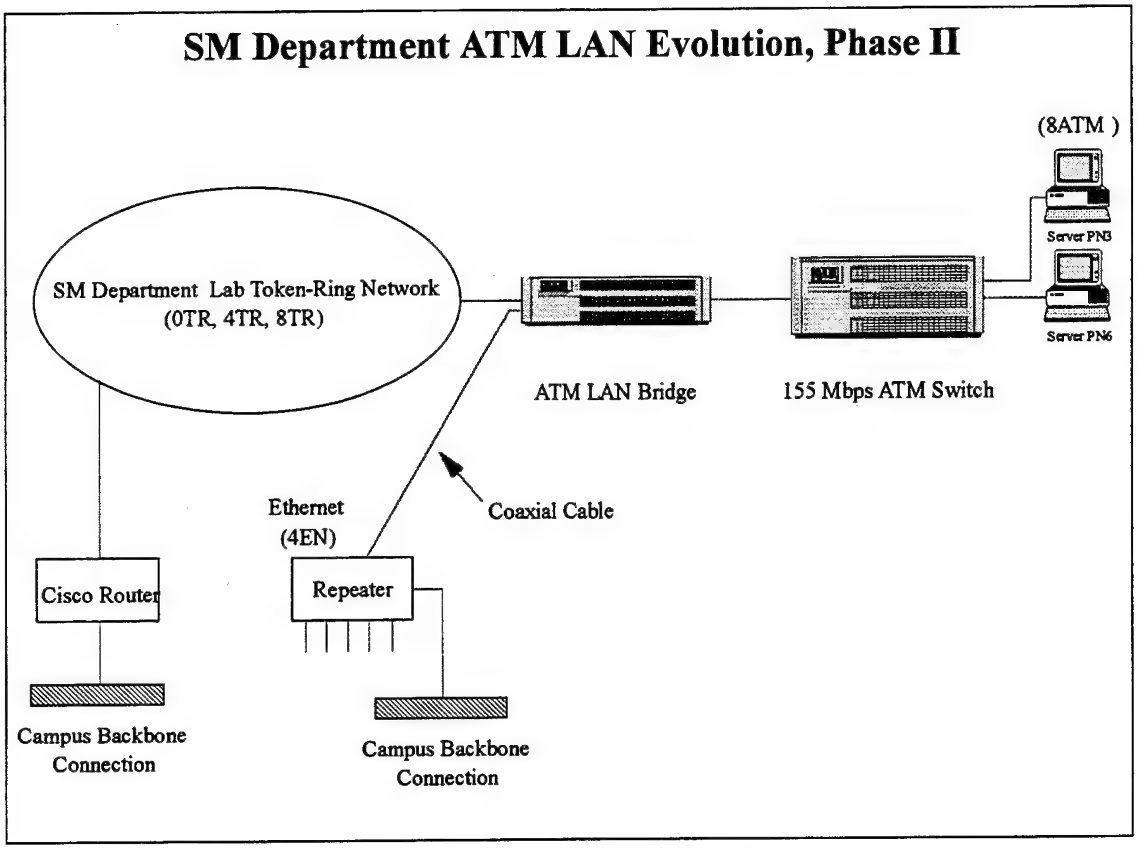

Figure 6.2 SM Department ATM LAN Evolution, Phase II

4. Phase III: Disable 4EN Backbone Connection

In Phase III, the Ethernet campus backbone connection is disabled. However, the AUI cable run will remain in place. By leaving the cable in place, this links can be used as a secondary or backup backbone connection should the Token-Ring backbone connection becomes inactive.

The Ethernet users will still have access to the campus backbone via the ATM LAN Bridge and Segment 4TR (Token-Ring). With this access, the Ethernet users keep their internet capabilities.

Figure 6.3 shows the disabling of the Ethernet campus backbone connection.

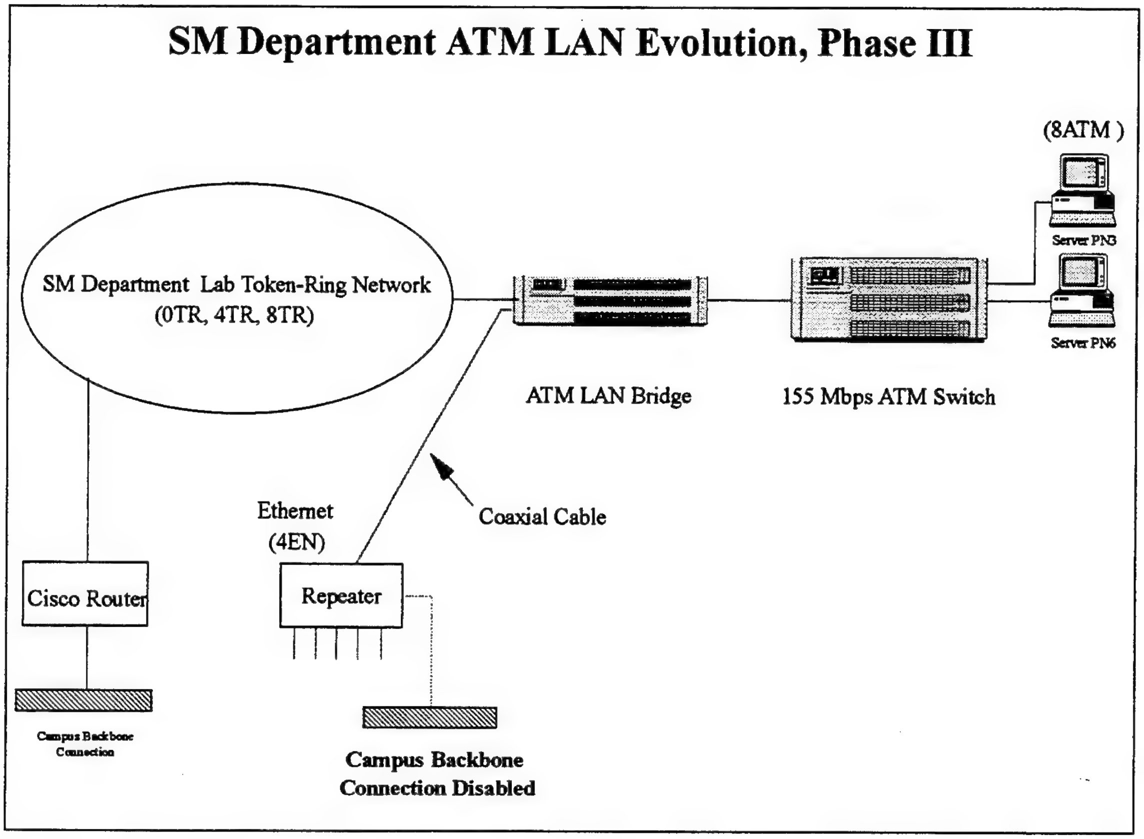

Figure 6.3 SM Department ATM LAN Evolution, Phase III

5. Phase IV: Upgrade Four IN-224 Computers to ATM

Phase IV involves migrating computers from Token-Ring to ATM. This stage will require the installation of multi-mode fiber cable from IN-224 to IN-158 to connect a 25.6 Mbps ATM Switch to the high-speed 155 Mbps ATM Switch. The connection will require two 155 Mbps Line Interface Cards, one for each switch, and the appropriate connectors.

After connectivity between the switches have been established, and the switches have been configured, computers can be connected to the ATM25 Switch. ATM NICs, and STP or UTP cable are necessary to make these connections. The ATM25 Switch, NICs, and cable must be compatible to obtain a connection.

As shown in Figure 6.4, the 4ATM segment co-exists with all three Token-Ring segments and 4EN. The users in 4ATM will be able to communicate with the servers and other users of the integrated network.

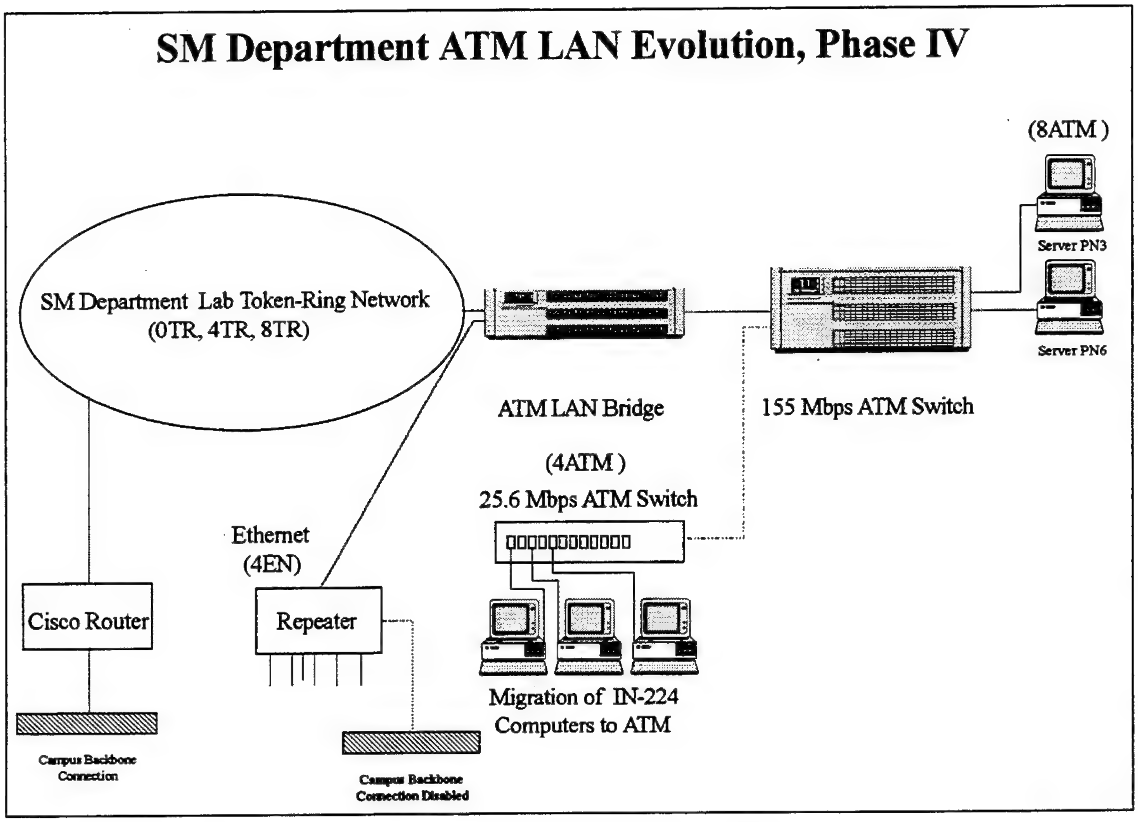

Figure 6.4 SM Department ATM LAN Evolution, Phase IV

6. Phase V: Upgrade Four IN-250 Computers to ATM

During Phase V, several computers in IN-250 will be converted from Token-Ring to ATM. This stage will require the installation of multi-mode fiber cable from IN-250 to IN-158 to connect a 25.6 Mbps ATM Switch to the high-speed 155 Mbps ATM Switch. Like the IN-224 and IN-250 ATM link, this connection will require two 155 Mbps Line Interface Cards, one for each switch, and the appropriate connectors. The same procedures done to connect the computers in IN-224 to that ATM25 Switch is required to connect the computers in IN-250 to an ATM25 Switch.

Figure 6.5 illustrates the progression in the integrated network, with the addition of the ATM25 Switch in IN-250.

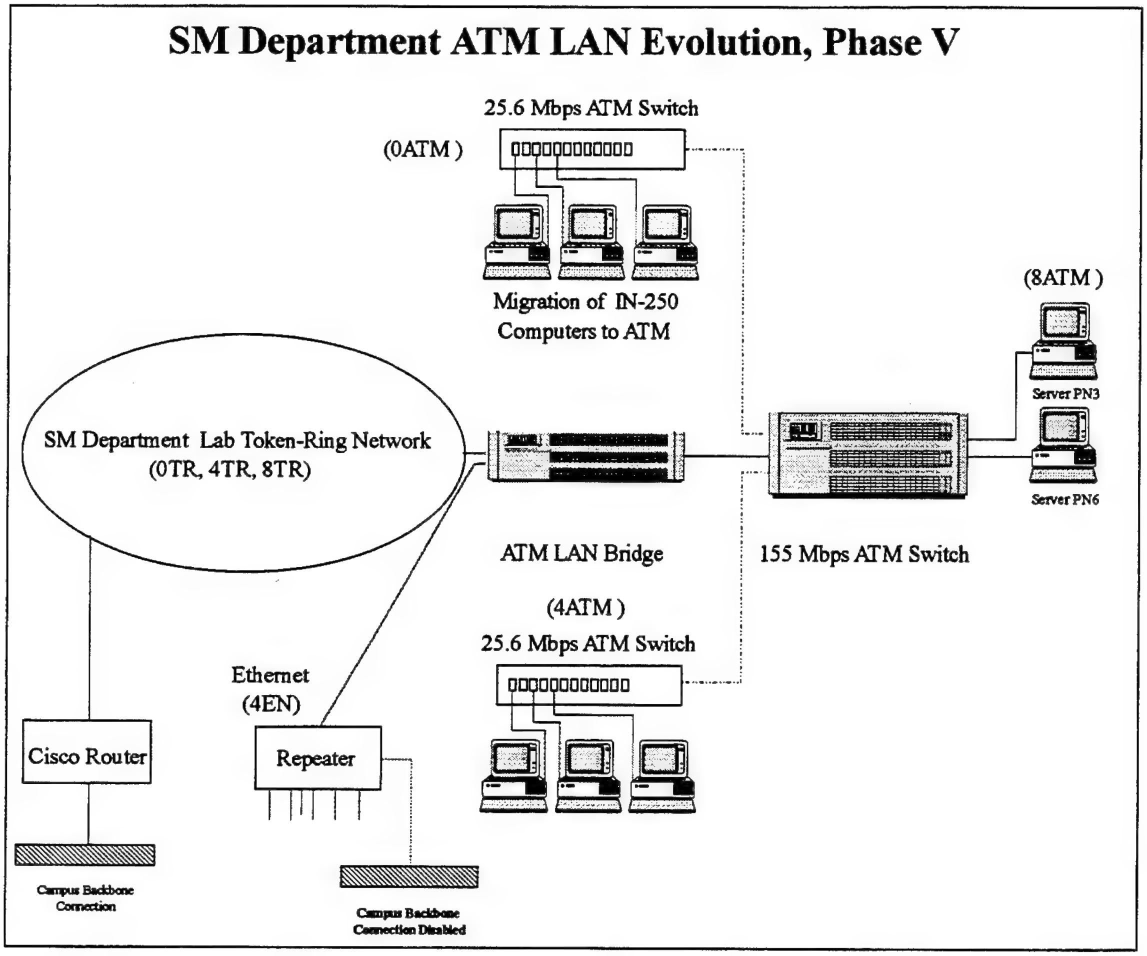

Figure 6.5 SM Department ATM LAN Evolution, Phase V

7. Phase VI: Convert All IN-250 Computers and 13 IN-224 Computers

Phase VI is the final stage in evolving the SM Department Lab LAN from Token-Ring and Ethernet technologies to an integrated network comprised of ATM, Token-Ring, and Ethernet technologies. This phase entails upgrading all but three Token-Ring configured computers in IN-224 to ATM. All remaining Token-Ring configured computers in IN-250 will be upgraded to ATM. An additional switch is necessary for both rooms to accommodate the newly converted computers. These switches will be stacked on top of the original ATM25 Switches in each room using the Stacking Bus Option. The newly reconfigured stacked switches in IN-224 and IN-250 increase the capacity of each room to support 24 computers.

Only 17 computers in IN-224 will be upgraded to ATM, leaving three Token-Ring configured computers on Segment 4TR. Twenty-four of the 25 computers in IN-250 will be converted to ATM. The remaining computer in IN-250 can either remain on Segment 0TR. However, since the Pentium Servers in IN-158 will become the application servers for IN-250, fewer servers will be required in IN-250. As a result, all user computers, including the instructor computer, can be converted to ATM.

Even though the stacked switches in IN-250 is at maximum capacity, a third switch can easily be added to the stack should the number of ATM computers becomes 25 or greater.

Figure 6.6, on the next page, shows the implementation of Phase VI. This final implementation consists of the following:

- Segment 0ATM - Stacked ATM25 switches and 24 ATM configured computers;
- Segment 4ATM - Stacked ATM25 switches and 17 ATM configured computers;
- Segment 8ATM - an ATM155 Switch, ATM LAN Bridge, and two Pentium Servers. Additional high powered servers can be added the ATM155 Switch;
- Segment 4TR - a MAU, three computers, backbone connection, and an ATM LAN Bridge connection;
- Segment 8TR - a MAU, 486 Server, five clients, and an ATM LAN Bridge connection;
- Segment 4EN - Ethernet Repeater, five computers, a disabled backbone connection, and an ATM LAN Bridge connection.

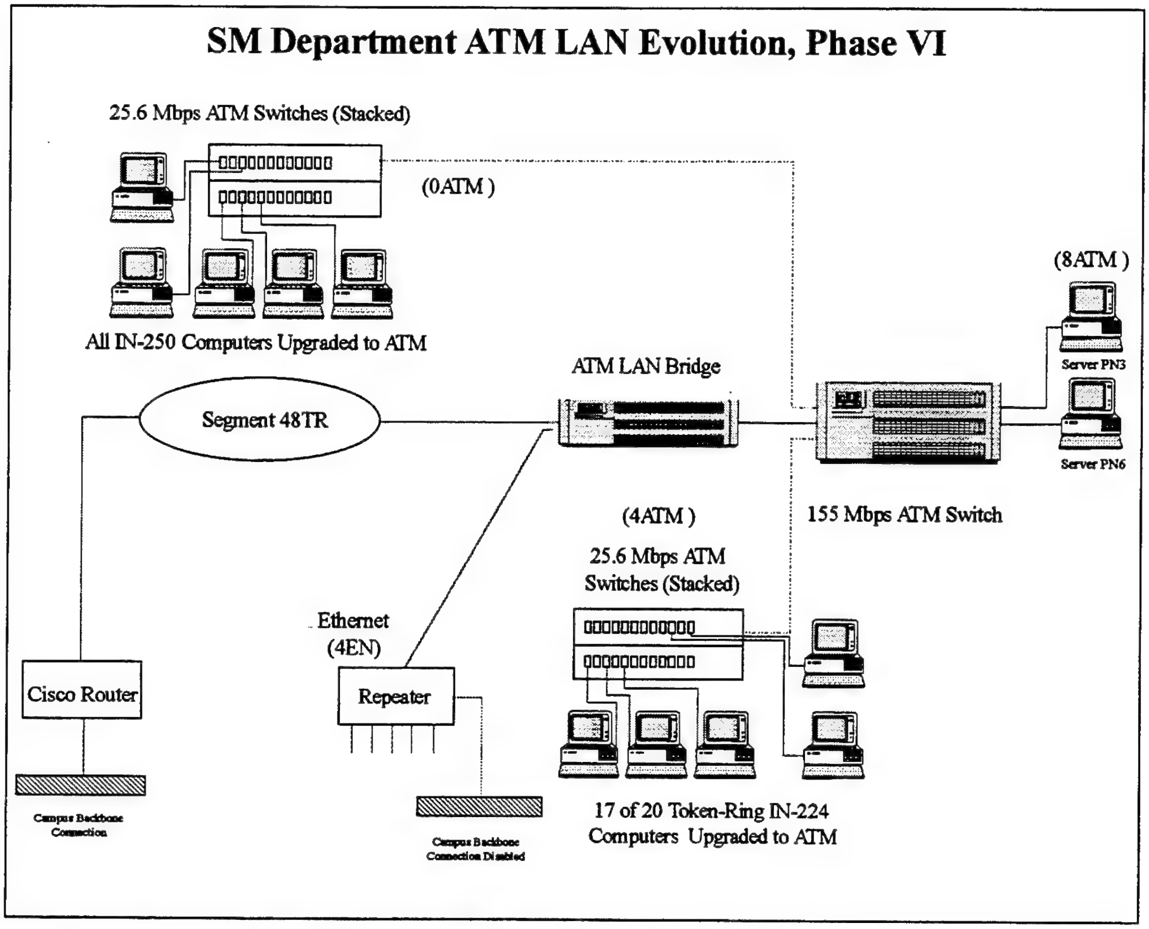

Figure 6.6 SM Department ATM LAN Evolution, Phase VI

C. THROUGHPUT LIMITATIONS

Though ATM is a "relative" new networking technology, it is growing in popularity and is being adapted by many companies and institutions. These organizations have realized the benefits ATM offers, such as a vast room for growth in bandwidth. Numerous other benefits are discussed in Chapter II.

Even with the on-going evolution of ATM standards, products (ATM switches, line interface cards, NICs, etc.) are being manufactured. Most of the products are in compliance with the existing ATM standards. As a result, these products can be procured and configured to form a fully functioning ATM network. The network can serve users within a single building or campus, or even users thousands of miles apart. The network

can support speeds ranging from 25.6 Mbps to 2.4 Gbps. The high throughput would support ATM backbones.

Though ATM supports these high rates of throughput, an Information Technology Manager must ask himself the following technical questions:

- Can the ATM network support all popular PC buses (ISA, EISA, PCI, NuBus), device drivers for my operating system (WFW, Windows NT, Novell Netware)?
- Does the ATM network emulate LANs for both ATM adapters and internetworking devices.
- Can my existing PCs or workstations handle ATM speeds?

Chapters II and V address the first two questions. Therefore, the next paragraphs will focus on throughput.

Communications Week tested four ATM switches during the summer of 1995. The tests focused on the switches' viability as desktop network interfaces. The switches included Fore Systems Inc.'s ForeRunner ASX-200BX, Newbridge Networks Inc.'s Vivid ATM Workgroup Switch, 3Com Corp's Cellplex 7000, and UB Networks Inc.'s GeoSwitch/155. Though these switches provided 155 Mbps bandwidth, the throughput tests performed by Communications Week illustrate the bottleneck of the network when using ATM technology. (Mier, E. E., Smithers, R. J., Jr., 1995, p. 129)

Communications Week implemented single-ATM-switch LANs, connected Pentium-based PC workstations to the switches using 155 Mbps multi-mode fiber adapters, and transferred real data traffic over TCP/IP. Each Pentium computer had 64 Mbytes of RAM, and a clock speed of 90 MHz. Half of the PCs ran Window NT Server 3.51, and the remaining half ran Windows NT Workstation 3.51.

Communications Week tested the throughput speeds of the 155 Mbps (bi-directional) ATM network and an Ethernet running at 10 Mbps. The technicians determined that the effective user data throughput over Ethernet, within a Windows NT Workstation and a Windows NT Server as the only active nodes, was 4 Mbps. The file size was 323 megabytes.

The same file was transferred over the ATM PVC. The data transferred at an effective rate of 13 Mbps. As one can see, this is nowhere near 155 Mbps. Disk I/O limited the transfer rate to 13 Mbps.

To perform the file transfer without conducting disk I/O functions, the technicians performed a cache memory-to-cache memory transfer of a 50 megabyte file (the cache could not hold the 323 megabyte file). The effective transfer of the 50 megabyte file was 30 Mbps, also much smaller than the 155 Mbps.

These throughput rates would have been much smaller had Communications Week used PCs with configurations identical to the PCs in the SM Department computer labs. Even ATM 25 Mbps switches would not have been used to their fullest potential.

Though ATM 25 Mbps switches exceed the throughput limitations of the SM Department Computer Lab LAN, the switches would allow room for growth and expansion of the network. As newer and more powerful PCs replace the existing 486 PCs, the overall throughput speed would increase.

D. CHAPTER SUMMARY

This chapter discussed the proposed implementation strategy to incorporate ATM technology into the SM Department Lab LAN. The strategy pursued a course which would minimize disruption, downtime, maintenance, and training. In the six phases, existing hardware and software are used to the fullest extent to minimize costs and risks.

Because of the redesigned and proposed implementation of the LAN, Token-Ring, and Ethernet became an integral part of the ATM LAN. This is accomplished through LAN Emulation. By having all three technologies in one integrated network, the students and staff will gain tremendous experience on these three networking technologies and how they function in one integrated environment.

One key advantage of the integrated network is that users will retain the ability to use existing applications through the use of LAN Emulation. The users will also have greater throughput with room for bandwidth growth as applications become more powerful, and demand additional bandwidth.

Lastly, the ATM segments will have the ability to support data, voice, and video transmission. Though the SM Department Lab users currently transmit text, future information technology procurements may include more powerful servers and clients. These computers may have multi-media capabilities which could possibly lead to the sharing of multi-media resources across the integrated network.

VII. CONCLUSION

User demand for additional bandwidth will continue to increase. In many cases, this demand will grow at a rate faster than workstation processing power. Since the SM Department is upgrading its computer lab network to WFW, and eventually to Windows NT, more powerful applications will be able to run on the network. These applications will require faster servers and clients, and additional bandwidth. Even if the servers and clients are replaced with much faster computers, the current Token-Ring and Ethernet technologies will be the limiting factor. These technologies only support 16 and 10 Mbps data rates, respectively, and are not capable of supporting the transmission of voice, data, images, and video.

ATM provides the throughput rates (25.6, 155, and 622 Mbps, and higher) and the capability to carry voice, data, images, and video. However, this technology comes with a high price tag and risks. One would not want to replace his existing shared-medium network with an ATM network in one phase. Instead, ATM technology should be phased into the existing network. This approach reduces risks, and maximizes the use of existing hardware and software. The migration or evolution strategy also allows time for the ATM standards to mature and to be implemented by manufactures. Cost also plays a critical role in the evolution strategy. It is expected that ATM prices will continue to decrease and become more competitive with other switching technologies such as Switch Ethernet and Switch Token-Ring.

Should the SM Department decide to upgrade the computer lab network to ATM, and elect to use the proposed migration strategy or even a different evolutionary plan, the manufacturers that provide the ATM technology will play a crucial role during and following the implementation. The manufacturers should be a member of the ATM Forum, adhere to ATM standards, and understand the ATM technology and its evolution.

If the manufacturers meet these criteria, the ATM products will be interoperable and compatible with other vendors ATM products; most of all, the products will function with existing LAN applications. The ATM equipment will also have a longer technology

life cycle (i.e., if a new ATM standard is released, the items can easily adapt the new standard, and not become obsolescence).

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APPENDIX A. ATM FORUM CURRENT WORK ITEMS

ATM FORUM CURRENT WORK ITEMS AS OF DECEMBER 1995 The ATM Forum Technical Committee			
Technical Working Group	**Principal Work Effort**	**Status**	**Approval Forecast**
Lan Emulation Chairman: Kieth McCloghrie	LANE V2.0 LUNI Interface LANE V2.0 Server-to-server Interface LANE 1.0 Addendium, af-lane-0050.000 LANE Service MIBs	Work In Progress Work In Progress Final Ballot Straw Ballot	10/96 10/96 2/96 4/96
MPOA Chair: George Swallow	Specific Development	Work In Progress	2/97
Traffic Mgmt Chair: Natalie Giroux	Traffic Management 4.0 Service Architecture ABR (Available Bit Rate) QoS (Quality of Service)	Straw Ballot	2/96
Service Aspects and Application Chair: Dean Skidmore	Native ATM Services: Semantic Description Audio/Visual Multimedia Services V1.0 FUNI (Frame-based User-to-Network Interface) Circuit Emulation Directory Services Voice & Telephony over ATM	Final Ballot Final Ballot Approved Approved Work In Progress Work In Progress	2/96 2/96 10/95 10/95 10/96
P-NNI Chair: Mike Goguen	P-NNI V1.0 (Private Network-to-Network Interface) MIB contains P-NNI Signaling and Routing Protocols	Straw Ballot	4/96
Physical Layer Chair: Rick Townsend	E-1 25.6 Mbps 155 UTP-3 622 Optical ATM Inverse Mux Utopia Level 2 Wire (PMD to TC layers) E3 UNI DS3 Physical Layer Interface Spec 120 Ohm Addendum to ATM PMD Interface Spec for 155 Mbps over TP, af-phy-0053.000	Straw Ballot Approved Final Ballot Final Ballot Work In Progress Straw Ballot Work In Progress Approved Final Ballot Straw Ballot Straw Ballot	4/96 10/95 2/96 2/96 2/96 10/95 2/96 4/96 4/96
Signaling Chair: Tom Helstern	UNI Signaling 4.0	Straw Ballot	6/96
B-ICI Chair: Richard Breault	B-ICI 2.0	Straw Ballot	4/96
Network Management Chair: Roger Kosak	M4 Public Network view M4 SNMP MIB Network Element M3 (CNM) Update M4 Public Network view SNMP & CMIP MIB Power Management M5 Carrier Interface	Final Ballot Work In Progress Work In Progress Work In Progress Work In Progress Work In Progress	2/96 4/96 6/96 6/96 9/96 9/96

Testing Chair: Gregan Crawford	PICS for AAL (ITU spec) PICS for Signaling (UNI V3.0) PICS for Signaling (UNI V3.1) Conformance Abstract Test Suite for ATM layer (End Sys) Conformance Abstract Test Suite for the AAL5 Sub-Layer Conformance Abstract Test Suite for SSCOP Sub-layer Conformance Abstract Test Suite for Signaling (UNI 3.1) - User Side Conformance Abstract Test Suiite for UNI 3.1 at the ATM Layer for Intermediate Systems PICS for UTP-3 (52 Mbps) 16 CAP Physical Layer PICS for the 25.6 Mbps over UTP-3 Physical Layer Conformance Abstract Test Suite for the UNI 3.1 ATM Layer of End System	Final Ballot Tabled Work In Progress Approved Final Ballot Work In Progress Work In Progress Approved Final Ballot Final Ballot Straw Ballot	12/95 10/95 2/96 12/95 2/96 2/96 4/96
RBB (Residential Broadband) Chair: Stanley Ool	Requirements for Specification: RBB Specification	Work In Progress	12/96
Security Chair: Mohammed Peyravian	Security 1.0	Work In Progress	2/97
Work in Progress: All work up to release of working docummen for Straw Ballot. Straw Ballot: Specification released for test vote with comments (some may require two rounds). Final Ballot: Final specification presented for vote or membership. Approval: Approval vote received.			

APPENDIX B. THE ATM REPORT GUIDE TO LANE PRODUCTS

ATM Switches, Hubs, & Routers			
Company	**Product**	**LAN Emulation**	**IETF IP over ATM**
Agile	ATMizer 125 ATM Switch	ATMF LANE 1.0	RFC 1483
Alantec	PowerCell 350 module for PowerHub 3000/5000 & PowerHub 3160 Power Cell 700 PowerCell 600	FORE LANE ATMF LANE 1.0 - 1Q 96 ATMF LANE 1.0 - 1Q 96 ATMF LANE 1.0 - 1Q 96	 RFC 1577 - 1Q 96 RFC 1577 - 1Q 96
ATM Inc.	Virata Switch	ATMF LANE 1.0	
Bay Networks	EtherCell Switch LattisCell System 5000AH ATM Module Backbone Node Routers (BLN & BCN)	ATMF LANE Client ATMF LANE 1.0 AMTF LANE 1.0 AMTF LANE 1.0	RFC 1483 RFC 1483 & 1577
Cisco	Cisco 7000 with AIP Cisco 4500/4700 with NPN Cisco IOS for ATM Software Cisco Catalyst 5000	ATMF LANE 1.0 ATMF LANE 1.0 AMTF LANE 1.0 AMTF LANE Clinet	RFC 1483 & 1577 RFC 1483 & 1577 RFC 1483 & 1577
3Com	CELLplex 7000 & 7200 ATM Module LinkSwitch 2700	AMTF LANE 1.0 AMTF LANE Client w/SVCs	
CrossComm	XLT-F Edge Router AES ATM/Ethernet Edge Switch	ATMF LANE Client AMTF LANE 1.0 Client 1Q 96	RFC 1483 & 1577 RFC 1483
Digital	GigaSwitch ATM DECNIS ATMcontroller 631	AMTF LANE 1.0	RFC 1483 & 1577 RFC 1483 & 1577
First Virtual	Media Switch	AMTF LANE 1.0	RFC 1483 & 1577
FORE	ASX-1000 & ASX-200 WG* & ASX-200BX	FORE LANE 0.4 ATMF LANE 1.0 - 1Q 96*	RFC 1483 & 1577
IBM	8281 ATM LAN/Bridge 8285 ATM Workgroup Switch	IBM LANE AMTF 1.0 - 1Q 96	RFC 1483 & 1577 RFC 1483 & 1577
Madge	Collage 250 - 1Q 96 Collage 280	ATMF LANE 1.0	
Newbridge VIVID	Vivid Switches & Bridges	Newbridge MPOA	RFC 1483
NSC	ERS	ATMF LANE 1.0	
ODS	Warrior Switch FORE Module AnyCell ATM25	ATMF LANE 1.0 FORE LANE IBM LANE	RFC 1483 & 1577
UB Networks	GeoSwitch/155	ATMF LANE; Client & Server services	
Whitaker (Hughes LAN)	Enterprise Hub Ethernet Switch with ATM	ATMF LANE 1.0 ATMF LANE 1.0	
Whitetree	Whitetree WS3000	ATMF LANE 1.0	
Xyplex	520 ATM Edge Router Module	ATMF LANE 1.0 - 1Q 96	RFC 1483, 1577 - 1Q 96

Xylan	OmniSwitch with OmniCell ATM Matrix - Q1 96 7000 Series	ATMF LANE 1.0 - 1Q 96 ATMF LANE 1.0	RFC 1483 & 1577

ATM NICs			
Company	**Product**	**LAN Emulation**	**IETF IP over ATM**
Adaptac	ATM 155 for SBus & PCI Bus ATM25 for PCI, SBus, Micro Channel	ATMF LEC	RFC 1577
ATM Inc.	Virata Link	ATMF LANE 1.0 Client	
3Com	ATMLink 155 Mbps for SBus	AMTF LANE	RFC 1577
Digital	ATMworks 750 & 350 for Turbo channel & PCI	AMTF LANE Client	RFC 1577
Efficient Networks	155 Mbps SBus, PCI, EISA 100 Mbps SBus, EISA 25 Mbps PCI - 1Q 96	ATMF LANE 1.0	RFC 1577/1755
First Virtual	Media Adapter 25 Mbps	AMTF LANE 1.0 Client	
FORE	ATM NICs for Sbus, EISA, GIO, MCA, VME, NuBus, PCI, MAC-PCI	FORE LANE ATMF LANE 1.0 - 1Q 96	RFC 1483/1577 - 1Q 96
IBM	TurboWays 25/100/155 Mbps NICs for ISA, MCA	IBM LANE AMTF 1.0 - 1Q 96	
Interphase	155 Mbps PCI, Sbus, EISA, VME, GIO, PMC 100 Mbps SBus, EISA, VME	ATMF LANE	RFC 1577 (SVCs) RFC 1483 (PVCs)
Madge	Collage 25/155 Mbps NICs for PCI	ATMF LANE 1.0	
Packet switch Tech.	IAX-210 155 Mbps PCI NIC		RFC 1577
SysKonnect	SK-NET 155 Mbps NICs for SBus, EISA, & PCI		RFC 1577
ZeitNet	155 Mbps NICs for PCI, SBus, EISA, & GIO	LANE Client, Server, & BUS	RFC 1483 & 1577

* - Fore ASX-200WG LANE server software supports diretly attached clients only. FORE will offer ATMF LANE 1.0 compliance on all products by 3/96.

MPOA - Multiprotocol over ATM

RFC 1483 - defines the encapsulation of IP datagrams directly in AAL5.

RFC 1577 - is intended to make IP run over ATM as efficiently as possible.

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